Course in
armaceutical Arithmetic.

J. W. Sturmer.

Prof. Charles F. Heebner
Toronto

Dis.

COURSE IN

PHARMACEUTICAL ARITHMETIC

INCLUDING

WEIGHTS AND MEASURES

By
JULIUS WILLIAM STURMER, PH. G.,
Professor of Pharmacy, Purdue University.

TERRE HAUTE, IND.:
MOORE & LANGEN PRINTING CO.
1903.

PREFACE.

In this little volume the writer offers a course in pharmaceutical arithmetic adapted to the requirements of students and pharmacists whose mathematical education has been limited, but who, nevertheless, desire to master the problems which come up in pharmaceutical practice.

The subjects have been arranged in logical sequence, thus forming a *Course;* the student is therefore advised to take up the chapters in their order, omitting only such matter as he is thoroughly familiar with.

It has been the writer's aim to make all explanations and deductions in language so simple that the student working without the aid of an instructor should meet with no serious difficulties.

The problems in percentage, in fortification and dilution, as well as the chemical problems, are solved by proportion, the principles of this branch of arithmetic having been expounded at some length. In this way a multitude of rules and formulas are rendered superfluous.

Since there appears to be much confusion in regard to the meaning of percentage in prescription work, this subject has received special attention, and weight-percentage, volume-percentage, and weight-to-volume-solutions have been discussed in detail.

The problems in Chapter I are intended primarily to familiarize the student with the values of the units of weights and measures.

Acknowledgement is due to the Office of Weights and Measures, U. S. Treasury Department, and to O. Oldberg, whose manual on Weights and Measures was freely consulted.

J. W. Sturmer.

Purdue University, Lafayette, Ind.

CONTENTS.

CHAPTER I.

WEIGHTS AND MEASURES.

A.—The Metric System.

The most important feature of the metric system is that the units of each of its branches are in decimal progression. Ten of any unit make one of the next higher, ten of which in turn make one of a still higher value ; etc. The system thus is in conformity with our arithmetical notation; and denominate numbers in metric units can be added, subtracted, multiplied, and divided as readily as abstract numbers. In this lies the chief practical advantage of the metric system over the other systems in vogue.

The branches of the metric system are: (1) linear measure, (2) surface measure, (3) cubic measure (dry measure), (4) cubic measure for liquids (volume measure), (5) and weight.

The relationship between these branches is a very simple one—a fact constituting the second great advantage of this system. The primary unit of linear measure—the *Meter*—is the basis of the entire system. Thus, the primary unit of surface measure, called *Are*, is the square of ten Meters. The primary unit of cubic measure (dry), the *Stere*, is the cube of one Meter. The primary unit of volume measure, the *Liter*, is the cube of one-tenth of a Meter. And the primary unit of weight, the *Gramme*, is the weight of a cubic $\frac{1}{100}$ Meter of water, at its greatest density, and weighed in vacuo.*

For convenience in measuring, secondary units, some larger,

***Their relationship has been slightly altered by inaccuracy in the weighings made when the first metric weight was constructed. See page 12.**

and some smaller than the units already referred to, were established. These secondary units, as has been stated, differ from each other by ten or by some power of ten. The names for the secondary units are formed by joining certain Greek and Latin prefixes—Greek for multiples, Latin for the fractionals —to the name of the unit itself.

The prefixes used are:

$$\text{Latin}\begin{cases}\text{milli} = \text{thousandth } (\tfrac{1}{1000})\\ \text{centi} = \text{hundredth } (\tfrac{1}{100})\\ \text{deci} = \text{tenth } (\tfrac{1}{10})\end{cases}$$

$$\text{Greek}\begin{cases}\text{deka} = \text{ten } (10)\\ \text{hecto} = \text{hundred } (100)\\ \text{kilo} = \text{thousand } (1000)\\ \text{myria} = \text{ten-thousand } (10000).\end{cases}$$

Thus we have *milli*meter, *milli*liter, *milli*gramme; *centi*meter, *centi*liter, *centi*gramme; etc.

Rules for capitalizing names of units.— The names of the primary units—Meter, [Are, Stere], Liter, Gramme—are usually written with a capital, as are also the names of the secondary units larger than the primary ones; but the names of the units smaller than the primary units are written with a small initial letter. Examples: *Deka*meter, but *deci*meter; *Myria*gramme, but *milli*gramme. These rules, as will be seen, serve to decrease the similarity in appearance between the names of certain multiples and certain fractionals. However, the rules are not universally observed, and in many scientific works the names of all units are written with small initial letters.

Abbreviations.—The abbreviations for primary units are: Meter = M; Liter = L; Gramme = Gm.

The abbreviations for the prefixes are:—milli = m; centi = c; deci = d; Deka = D; Hecto = H; Kilo = K; Myria = M.

To construct the abbreviation of any secondary unit, the

abbreviation of the prefix is coupled with the abbreviation for the primary unit. Thus Kilometer = Km.; millimeter = mm.; milliliter = ml.; centigramme = cgm.; etc.

The rules given for the capitalizing of names of units apply likewise to their abbreviations; Dm. being used for Dekameter, dm. for decimeter, Mgm. for Myriagramme, and mgm. for milligramme. But in the U. S. Pharmacopœia *all* abbreviations of metric units are capitalized; millimeter = Mm., centimeter = Cm., milligramme = Mgm. In ordinary practice this might lead to confusion. In the Pharmacopœia, however, no ambiguity occurs, simply because the multiples of the primary units are not in use in its text; so Mm. must stand for millimeter, for the Myriameter is non-existent as far as the Pharmacopœia is concerned.

1. Linear Measure.

The primary unit of length, the Meter, may be defined as the $\frac{1}{40000000}$ of the earth's circumference, measured across the poles. The distance from the equator to the north pole was calculated from surveys made along the meridian which passes through Paris; and this distance, divided by 10,000,000, was chosen as the unit of length.*

It is deemed desirable that a system of measure be based upon some unalterable object in nature, in order that the correctness of the measures accepted as models may be re-determined, should this become necessary. The metric system is based upon the dimensions of the earth—an object ill adapted for a "natural standard"; firstly because it is not absolutely unalterable, and secondly because of the difficulty of obtaining its measurement. A far betser "natural standard" is the second's pendulum, upon the length of which the English measure is now based. See page 23.

* According to recent measurements the earth's quadrant measures 10,000.880 Meters, and the actual Meter is therefore a trifle shorter than the theoretical Meter which is $\frac{1}{10,000,000}$, and not $\frac{1}{10,000,880}$ of the quadrant.

Table of Linear Measure.

Table A.

10 millimeters (mm.) = 1 centimeter (cm.)
10 centimeters = 1 decimeter (dm.)
10 decimeters = 1 Meter (M.)
10 Meters = 1 Dekameters (Dm.)
10 Dekameters = 1 Hectometer (Hm.)
10 Hectometers = 1 Kilometer (Km.)
10 Kilometers = 1 Myriameter (Mm.)

For microscopic measurements the micro-millimeter, which is $\frac{1}{1000}$ of a millimeter, is used. It is usually written micron or mikron, and abbreviated mkm.

Table B.

Kilometers		*Hectometers*		*Dekameters*		*Meters*		*decimeters*		*centimeters*		*millimeters*
1	=	10	=	100	=	1000	=	10000	=	100000	=	1000000
		1	=	10	=	100	=	1000	=	10000	=	100000
				1	=	10	=	100	=	1000	=	10000
						1	=	10	=	100	=	1000
								1	=	10	=	100
										1	=	10

Units in Common Use.—Units larger than the Meter are seldom employed in pharmaceutical literature. As has been stated on page 9, the U. S. Pharmacopœia ignores the larger units, and in its text mm. and cm. are capitalized without danger of ambiguity.

4. Cubic Measure for Fluids. [Volume Measure.]*

The primary unit of volume, the *Liter* [pronounced Leeter, not Laiter], is the cube of one decimeter.

But the Liter measures in actual uses are standardized to hold a certain weight of pure water (see page 12); and since

***The surface measure, and the cubic measure for solids (dry measure) are not used in pharmacy; hence are omitted.**

the less exact methods of measuring and weighing, used a hundred years ago, resulted in the adoption of a metric standard weight which was too light, the Liter measures, likewise, are too small to hold 1 cubic decimeter. The error amounts to nearly .06 percent. Thus we have the *theoretical* Liter, which is the cube of 1 dm.; and the *actual* Liter, which is the volume of a certain weight [1 Kilogramme, actual] of pure water, and is about .9994+ of a cubic decimeter.

Tables of Volume Measure.

Table A.

10 milliliters (ml.) = 1 centiliter (cl.)
10 centiliters = 1 deciliter (dl.)
10 deciliters = 1 Liter (L.)
10 Liters = 1 Dekaliter (Dl.)
10 Dekaliters = 1 Hectoliter (Hl.)
10 Hectoliters = 1 Kiloliter (Kl.)
10 Kiloliters = 1 Myrialiter (Ml.)

The milliliter is commonly called cubic centimeter; to which it bears the same relation that the Liter bears to the cubic decimeter. The abbreviation for cubic centimeter is c.c., c.cm., or, as in the Pharmacopœia, Cc.

Table B.

Myrialiter		*Kiloliter*		*Hectoliter*		*Dekaliter*		*Liter*		*deciliter*		*centiliter*		*milliliter*
1	=	10	=	100	=	1000	=	10000	=	100000	=	1000000	=	10000000
		1	=	10	=	100	=	1000	=	10000	=	100000	=	1000000
				1	=	10	=	100	=	1000	=	10000	=	100000
						1	=	10	=	100	=	1000	=	10000
								1	=	10	=	100	=	1000
										1	=	10	=	100
												1	=	10

Units in Use.—In pharmaceutical and chemical works only two units are commonly used: the Liter, and the milliliter, which latter, however, is almost invariably called the cubic

centimeter. The table of volume measure, as actually used, is:

1000 cubic centimeters = 1 Liter.

While the other units are unnecessary, they appear occasionally in books and periodicals, making a familiarity with *all* units a desideratum if not a necessity.

5. WEIGHT.

The primary unit of weight, the Gramme, is defined as the weight *in vacuo** of one cubic centimeter of water, at its greatest density (4°C.).

Note.—Recent determinations of the weight of water under standard conditions, and with the most delicate balances, have shown that the original Kilogramme weight, which has served as the modelfor over 100 years, is about .58 Grammes too light to represent the weight of 1 cubic decimeter of water. The primary unit itself, the Gramme, is, therefore, .00058 Gm. lighter than was intended. But as the units of volume were made correspondingly smaller, one cubic centimeter (actual) being the volume of one Gramme (actual) of water. and one Liter (actual), the volume of one Kilogramme (actual), this error in the construction of the original Kilogramme weight has no practical bearing.

In pharmacy the name of the primary unit of weight is always spelled according to French orthography—*Gramme.* The English spelling, *gram*, gives to the word too great a similarity to the word grain—the name of a unit of weight of he Apothe caries' System of Weight. The pronunciation is

*Weight in a vacuum is called *true weight*, in contradistinction to *apparent weight*, which is weight obtained in air, i. e., under ordinary conditions.

Air, like water, though in a lesser degree, exerts a buoyant force on bodies; tending to lift or float both the body being weighed and the weights used. This buoyant force is exerted on a body in proportion to its bulk. Hence, if there is a difference in bulk between the body weighed and the weights used, there will be a corresponding difference in this buoyant force, and the weight obtained will not be truly proportional to mass.

It follows also that this difference in buoyant force will fluctuate with the density of the air, i. e., with the barometric pressure. For this reason the barometer reading is taken into consideration in weighings where great accuracy is required, and weighing in vacuo is impracticable. See page 31.

gram, the *a* having the same sound as in Sam. The abbreviation is always capitalized, *Gm.*, lest it be mistaken for *gr.*, which is the abbreviation for grain.

Table A.

10 milligrammes (mg.) = 1 centigramme (cg., or cgm.)
10 centigrames = 1 decigramme (dg., or dgm.)
10 decigrammes = 1 Gramme (Gm.)
10 Grammes = 1 Dekagramme (Dg. or Dgm.)
10 Dekagrammes = 1 Hectogramme (Hg. or Hgm.)
10 Hectogrammes = 1 Kilogramme (Kg. or Kgm.)
10 Kilogrammes = 1 Myriagramme (Mgm.)

Table B.

Myria gramme	*Kilo gramme*	*Hecto gramme*	*Deka gramme*	*Gramme*	*deci gramme*	*centi gramme*	*mili gramme*
1 =	10 =	100 =	1000 =	10000 =	100000 =	1000000 =	10000000
	1 =	10 =	100 =	1000 =	10000 =	100000 =	1000000
		1 =	10 =	100 =	1000 =	10000 =	100000
			1 =	10 =	100 =	1000 =	10000
				1 =	10 =	100 =	1000
					1 =	10 =	100
						1 =	10

Units in Common Use.—In prescriptions, and in the U. S. Pharmacopœia, only one unit of weight—the Gramme—is used. In many scientific books and periodicals the decigramme, centigramme, and milligramme are used in addition. The Kilogramme is used in commercial transactions, and is frequently abbreviated to *Kilo*.

Metric Prescriptions.

Rules.—1. All volumes should be expressed in cubic centimeters, and all weights in Grammes.

2. Arabic numerals should be used in all cases; and the numbers should be placed before the abbreviations. Thus, 25 Gm., 160 Cc., 5 cm., etc.

3. Since so much depends upon the proper placing and the proper reading of the decimal point, special precautions should be observed to avoid a chance for a mistake. It is a common practice to draw a vertical line in the proper place on the prescription blank, and to write whole numbers of cubic centimeters or of Grammes to the left of the line, and the fractions beyond the line. Thus the decimal point is done away with, the line serving its purpose.

Example.—

℞	Quin. Sulph.	2	
	Ferri Phos.	8	75
	Potass. Citr.	8	75
	Syr. Calc. Lactophos.	125	
	Aquae	15	
	Elix. Arom. q. s.	500	

Since it is customary in this country to prescribe all liquids by measure, and all solids by weight, there is no difficulty in determining which numbers in a prescription stand for cubic centimeters, and which for Grammes. Quinine Sulphate being a solid, the "2" following this item in the prescription given, stands for 2 Gm. But the "125," expressing the quantity of the Syr. Calcium Lactophosphate, obviously means 125 Cc.; for the article is a liquid. and hence is to be measured.

If the vertical line is not made use of, every decimal fraction in the prescription should be written with a cipher before the decimal point. Thus, 0.75 Gm. in place of .75 Gm.; 0.1 Cc. in place of .1 Cc. This precaution makes it less probable that imperfections in the paper, or accidental markings be mistaken for decimal points. The German practice of using a comma (,), in place of a point, is also to be recommended. However, the vertical line removes the chances for such mistakes entirely.

Reading Metric Quantities in Prescriptions.—A whole number expressing a metric quantity is always read as a simple de-

nominate number, and not as a compound number; that is, only one unit is used, no matter how large the number. Thus, 3450 Gm. is read—three thousand four hundred and fifty Grammes;—not three Kilogrammes, four Hectogrammes, and five Dekagrammes, which would be unnecessarily cumbersome. 6565 Cc. is read— six thousand five hundred and sixty-five cubic centimeters;— not six Liters, etc., etc.

Fractions of cubic centimeters are read as tenths or hundredths, as the case may be. Fractions of Grammes are read as so many of the lowest unit in the fraction, it being remembered that the first decimal place belongs to decigrammes, the second to centigrammes and the third to milligrammes. According to this rule 0.5 Gm. would be five decigrammes; 0.55 Gm., fifty-five centigrammes; 0.555 Gm., five hundred and fifty-five milligrammes. In case of a fourth decimal, this is read as so many tenths of milligrammes; —0006 Gm. being read six-tenths milligrammes; and .3575 Gm., as three hundred and fifty-seven and five-tenths milligrammes.

Some pharmacists ignore the units, decigramme and centigramme, and read all fractions of grammes as milligrammes. Thus 0.5 Gm. would be five hundred milligrammes, and 0.55 Gm., five hundred and fifty milligrammes.

In dictating prescriptions by telephone, especially if there are mixed decimals to dictate, the plan of reading the numerals from left to right (in place of the whole numbers) should be adopted. The pharmacist can then copy the numerals as fast as read, and need not hold the entire number in his mind—a task which is very trying, and may lead to error.

To illustrate: the prescription—

℞	Arsenous Acid	.065
	Ext. Opium	.48
	Quinine Sulphate	8.75
	Make 65 pills.	

Would be telephoned—

Arsenous Acid—point—nought—six—five,
Ext. Opium—point—four—eight,
Quinine Sulphate—eight—point—seven—five.
Make 65 pills.

Of course *Grammes* would be understood.

Metric Prototypes.

As has been stated, the metric system was based on the $\frac{1}{10000000}$ of the earth's quadrant. A bar of platinum was constructed of this length, and was deposited in the French Archives, to serve as a prototype or model for the meter measures intended for actual use.

There was also constructed, and deposited in the French Archives, a weight of platinum of such size as to counterpoise in vacuo one cubic decimeter of water at its greatest density. This weight constituted the fundamental standard of mass, and was to serve as a prototype or model for the Kilogramme weights (and indirectly for the other metric weights) intended for actual use.

The metric system was adopted by France in 1795. The prototypes referred to became the legal reference standards of France shortly after the adoption of the system.

In 1875 an International Metric Convention was held in Paris, the United States participating. This convention called into being an *International Bureau of Weights and Measures*, the first duty of which bureau consisted in preparing an international standard Meter bar, and an international standard Kilogramme weight, and duplicates of these for the seventeen countries which had contributed to the support of this bureau.

It was decided that the international prototypes and their duplicates should be made to equal (the Meter bars in length, and the Kilogramme weights in mass) the prototypes of the French Archives; and should be constructed of an alloy of 90 parts of platinum and 10 parts of iridium, a composition selected on account of its hardness and its resistance to the action of atmospheric gases.

Of the 30 Meter bars and 31 Kilogramme weights made, one Meter bar and one Kilogramme weight were selected as interna-

tional prototypes and placed in the charge of the international bureau. The others were distributed among the countries which had called the bureau into existence. The distribution was effected by lot, the United States drawing Meters No. 21 and No. 27, and Kilogrammes No. 4 and No. 20.

Meter No. 27 and Kilogramme No. 20 were selected as our *National Prototypes*, and are carefully preserved in the United States Office of Weights and Measures, which is a branch of the Treasury Department. The Meter No. 21 and the Kilogramme No. 4 are used as working standards.

While the 30 Meters and the 31 Kilogrammes were made as nearly alike as it was possible to make them, it was found that they were not precisely alike. But the difference between the International Prototypes and the several national prototypes was in each case determined with the utmost care. Thus our National Kilogramme (No. 20) was found to be .00003 Gm. too light; and this fact must be taken cognizance of in the standardizations of other weights.

The two National Prototypes—the Meter No. 27 and the Kilogramme No. 20—are at the present time the ultimate reference standards for *all* weights and measures in use in the United States, with the sole exception of the weights used in the U. S. mints, which weights are by law still referable to the standard troy pound received from England in 1827.

Advice to the Student.

The student is advised to acquaint himself with the metric length units by the use of a metric rule; with the volume units by means of measuring vessels graduated in cubic centimeters and Liters; with the units of mass, by means of a set of metric weights. The Gramme, and the cubic centimeter should be known to the pharmacist as the pound and pint are known to the grocer—from actual use of the weights and measures. It is a mistake to think of the Liter as equivalent to so many fluid ounces, and of the Gramme as so many grains. Such equivalents have their uses; but the student must become familiar with the metric units by using measures and weights;—not through equivalents. To learn

French properly, one must learn to *think* in French—not to think in English and then to translate. In like manner, one must learn to *think* in metric units—to guess at the diameter of a filter in centimeters, the capacity of a flask in cubic centimeters, the weight of a mass of quinine in Grammes. It is for these reasons that the relationship between the metric system and the other systems is not taken up until the individual systems have been studied.

Problems and Exercises.

1. Write in numbers, followed by the proper abbreviations:—(a.) six milligrammes, as Grammes; (b.) six centigrammes as Grammes; (c.) six centigrammes, as milligrammes; (d.) six Grammes, as Kilogrammes; (e.) six Grammes, as centigrammes; (f.) six Kilogrammes, as Grammes; (g.) six decigrammes, as milligrammes; (h.) six Grammes, six decigrammes, six centigrammes, and six milligrammes, as Grammes.

2. Write in numbers, followed by the proper abbreviations:—(a.) five Liters, as cubic centimeters; (b.) five milliliters, as cubic centimeters; (c.) five Liters five deciliters five centiliters and five milliliters as cubic centimeters.

3. Read the following: —(a.) 6560 c.c.; (b.) .02 L.; (c.) 2 L., as c.c.; (d.) 16 Gm.; (e.) 1.645 Gm.; (b.) .16 Gm.; (g.) .016 Gm., (h.) 65 mg.; (i.) 6 cg.; (j.) 6 dg.; (k.) 6 Kg.; (l.) 6 Kilo.

4. Read the following:—(a.) 17 M.; (b.) 7 dm.; (c.) 70 cm.; (d.) 700 mm.; (e.) 6 Km.; (f.) 6789.123 M.; (g.) .0004 M.; (h.) .004 M.; (i.) .4 c.c.; (j.) .4 ml.

5. 18976.543 Gm.—read as Kilogrammes, as Hectogrammes, as Dekagrammes, as Grammes, as decigrammes, as centigrammes, as milligrammes.

6. Supply the proper abbreviations in the following formula:—

Guaiac	12	5
Potass. Carbonate		6
Pimenta	3	
Pumice	6	
Alcohol	43	5
Water	43	5
Diluted Alcohol q. s.	100	

ADDITION.

7. Add 5 L., 4 cl., 5 ml., 43 c.c.

Solution.—

5 L.	=	5000 c.c.
4 cl.	=	40 c.c.
5 ml.	=	5 c.c.
43 c.c.	=	43 c.c.
Sum	=	5088 c.c.

Suggestion.—Express all lengths in Meters, all volumes in cubic centimeters, all weights in Grammes. Then weights may be added to weights, volumes to volumes, and lengths to lengths, in the same manner in which abstract numbers are added. Thus, 4 decigrammes = 0.4 Gm.; and this can be added to 4 Gm., or to 40 Gm., as readily as .4 can be added to 4, or to 40.

8. Add: 10 L., 100 c.c., 5.6 L., 3.4 c.c.

9. Add: 2 Kg., 4 Dg., 500 Gm., 32 mg., .4 mg.

10. Add: 2 cm., 25 cm., 5 M., 500 mm., 13 Km.

11. Add: 5 cg., 50.5 mg., 5.5 Gm.

12. Add: 6 Kg., 20 Hg., 200 Dg., 2145 Gm.

Subtraction.

13. Subtract 345 c.c. from 5 L.

Solution.—5 L. = 5000 c.c.; and 5000 c.c. — 345 c.c. = 4655 c.c.

14. Subtract 345 mg. from 140.002 Gm.

Solution.—345 mg. = .345 Gm.; and 140.002 Gm. — .345 Gm. = 139.657 Gm.

15. (a.) Subtract 1 cm. from 500 mm.; (b.) 2 L from 6050 c.c.

16. (a.) Subtract 3.5 c.c. from 1 L.; (b.) 1.4 mg. from 10 Gm.

17. A druggist making solution of lead subacetate finds that his evaporating dish plus contents weighs 757 Gm. The dish itself weighs 289.02 Gm. How much water must be added to make the contents weigh 500 Gm.?

Multiplication.

Remarks.—The product is always in the same unit as the multiplicand. If mg. are multiplied, the product will be mg.; if Gm. are multiplied, the product will be Gm.; etc.

If a length, volume, or weight is expressed in a compound denominate number—that is, if several units are used in expressing it—reduce to a simple denominate number before multiplying.

Remember that the decimal places in the product must equal the total number of decimal places for both factors.

18. (a.) Multiply 345 mg. by 856; (b.) 5.045 Gm. by .004.

19. (a.) Multiply 50.5 c. c. by 7.058; (b.) 5 Kg. 35.5 Gm. by 430.

20. A prescription is received for 48 capsules, each to con-

tain .195 Gm. of mercurial mass, .12 Gm. of comp. ext. colocynth, .15 Gm. of ext. gentian. How much must be weighed out of each ingredient?

Division.

21. Divide 6 Kg. by 8.

Suggestion.—Since the number in the dividend is smaller than the number in the divisor, reduce to Gm. before dividing.

Remember that the quotient must have as many decimal places as those in the dividend exceed those in the divisor.

22. Divide 30 Kg. by 8.

Suggestion.—Since the number in the dividend cannot be divided by 8 without a remainder, it is simpler to reduce 30 Kg. to Gm. before dividing. It is not customary to express metric quantities by compound denominate numbers.

23. (a.) 1 mg. ÷ 200; (b.) 1 L. ÷ 1000; (c.) 5 L. ÷ .005; (d.) 5.789 ÷ .001.

24. A Seidlitz powder contains 7.75 Gm. of Rochelle salt. How many powders could be made from 2 Kg. of the salt?

Remark.—When a denominate number is to be divided by another denominate number, both must be in the same unit (denomination). The 2 Kg. should be reduced to Gm. before the division is performed.

Miscellaneous Problems.

25. A druggist receives four lumps of opium, weighing respectively (1.) 1 Kg. 20 Gm., (2.) 5 Hg. 3 Dg., (3.) 650.35 Gm., (4.) 205 Gm. 15 mg. How many Gm. of opium does he receive?

26. Suppose opium were worth $13.50 per Kilo. What would the above consignment cost?

27. A druggist opens a 100 Gm. bottle of calcium glycerophosphate, and uses 630 mg. in a prescription. How much remains?

28. A certain elixir is to contain .175 mg. of strychnine in each c.c. How much strychnine must be weighed out for 3 L. of the elixir?

29. A certain prescription calls for 75 pills, each to con tain 200 mg. of quinine sulphate. How much of the latt must be weighed out?

30. A prescription calls for 5.1 Gm. of pancreatin, to b mixed with 20.4 Gm. of sodium bicarbonate, and the mix ure to be divided into powders weighing 1.7 Gm. each (amount for peptonizing 500 c.c. of cow's milk). How many powders will the mixture make?

31.

℞	Strych. Sulph.		06
	Quin. Sulph.	16	
	Ferri Phos.	10	75

Mix and divide into 85 pills.

How much strychnine sulphate, how much quinine sulphate, and how much ferric phosphate in each pill?

32. A pharmacist extracts 7 headache tablets with chloroform, for the purpose of dissolving the caffeine present. He evaporates the chloroformic solution to dryness in a beaker, and finds that the residue and the beaker together weigh 11.005 Gm. The beaker itself weighs 10.38 Gm. How much caffeine in each tablet?

B. English Systems Customary in the United States.

While the metric system has had legal sanction since 1866, has since been adopted for all scientific work, and is the fficial system of our pharmacopœia, it has not as yet disaced the cumbersome English Systems in our every-day siness transactions. Lumber is still sold by the foot, cloth the yard, coal oil by the gallon, and meat by the avoirpois pound. For prescription work the use of the old glish troy weight—now obsolete in that country—is still uite general in the United States.

1. Linear Measure.

The English linear measure, with its units of inch, foot, ard, etc., was originally derived from the average length of e barley corn. According to an English law of the year 324, "three barley corns, round and dry, shall make an ich, and twelve inches a foot." But at the present time the inch is defined in England as the $\frac{1}{39.13929}$ of the length of the second's pendulum, which latter is therefore the natural standard of the English linear measure, and through the same, of all the English systems of measure and weight.*

The lack of simplicity in the relationship between the inch and the length of the second's pendulum—the latter being

*The length of a pendulum determines the time of its vibrations. The shorter the pendulum, the shorter are its vibrations; the longer the pendulum, the longer and slower are its vibrations. A pendulum 39.13929 inches in length will always make one complete vibration ("swing-swang") per second, provided the pendulum is placed in a vacuum, the temperature is 62° F., the altitude is that of the sea level, and the latitude, that of London. Conversely, a pendulum, beating seconds of time under the aforementioned conditions is bound to be just 39.13929 inches in length. And since a second's pendulum can be constructed as often as necessary, it serves admirably as a natural standard,—i. e., as a check upon the material standards in use.

39.13929 times that of the former—is readily accounted for by the fact that the length of the inch had become fixed by custom and by law, before the second's pendulum was selected as the natural standard.

In the United States the inch is now defined as equivalent to 25.4001 millimeters.

The yard is defined as $\frac{3600}{3937}$ Meters.*

As stated on page 17, all our customary measures and weights are now defined in metric terms, thus making the metric prototypes the standards for all the weights and measures in use in the United States, excepting the weights used in the U. S. Mint, which are still regulated by law by the standard troy pound, received from England in 1827.

To repeat:—the American and the British yard are identical in length; but the former has for its prototype the Meter bar No. 27 (see page 17) and for its natural standard, the earth's quadrant; while the British yard is referable to a certain bar, with a gold peg near each end, a bar deposited in the office of the Exchequer, London;—and the natural standard for the British yard is the second's pendulum.

Table A.

12 inches (in.) = 1 foot (ft.)
3 feet = 1 yard (yd.)

[Higher units are never used in pharmacy.]

Table B.

Yard		*Feet*		*Inches*
1	=	3	=	36
		1	=	12

*While $\frac{3600}{3937}$ Meters is the equivalent fixed by the law of 1866, and is accurate enough for all common purposes, the equivalent as determined by Capt. Clark for the British government is $\frac{36000000}{39370432}$.

2. Apothecaries' Fluid Measure (U. S. Wine Measure.)

The primary unit of the U. S. Wine Measure is the gallon, which is defined by the National Office of Weights and Measures as the volume in vacuo, and at 4° C., of 3785.434 Gm. of pure water.

Prior to 1893 the gallon was officially defined as 231 cubic inches, which shows its relation to the English Linear measure.

The Wine Measure, as used in this country, with its units of gallon, quart, and pint*, was brought from England, in which country, however, it has long since (1826) been superseded by the Imperial Measure.

The Apothecaries' Fluid Measure is the Wine Measure minus the quart unit, and with the addition of three units smaller than the pint.

The table, giving symbols and abbreviations, is as follows:

Table A.

60 minims (♏)	= 1 fluid drahm (f ʒ)
8 fluid drahms	= 1 fluid ounce (f ℥)
16 fluid ounces	= 1 pint (O.)
8 pints	= 1 gallon (Cong.)

O. is the abbreviation for the Latin word Octarius; Cong., for the Latin word Congius.

Table B.

Gallon		*Pint*		*Fluid Ounces*		*Fluid Drachms*		*Minims*
1	=	8	=	128	=	1024	=	61440
		1	=	16	=	128	=	7680
				1	=	8	=	480
						1	=	60

* The gill, which is ¼ pint, is obsolete.

Apothecaries' Measure in Prescription Writing.—Roman numerals are used in connection with this system. It is customary to place the symbol or abbreviation before the number—not after it, as in case of metric prescriptions.

Example:

℞	Tinct. Ferri Chloridi	fʒ iv
	Acidi Phosphorici Diluti	fʒ iij
	Spiritus Limonis	fʒ ij
	Syrupi q. s.	f℥ vj

Notes.—The dot over the numeral I is used as a precaution against ambiguity which might be occasioned by carelessness in writing. For example, ıȷ might stand for ij or for v; but if the dots are systematically used, their absence would prove the character to be a v, while their presence would prove it to be a ij.

Many physicians omit the f, writing ʒ for fʒ, and ℥ for f℥. Since liquids are measured, and solids weighed, the ʒ and ℥ stand respectively for fʒ and for f℥ in case of liquids, and for the weight units in case of solids.

Roman Numbers.

Numerals.—The Roman numerals are: I = 1; V = 5; X = 10; L = 50; C = 100; D = 500; M = 1000.

[ss., from semis, Latin for half, is used in prescriptions.]

Rules for combining the numerals.—

1. Repeating a numeral repeats its value. Thus, III = 3; XX = 20; CCC = 300; etc. But since V, L, and D if doubled would give the equivalent of X, C, and M respectively, these three first-mentioned are never doubled. In place of VV, X is used; in place of LL, C is used; etc.

2. Numerals placed after a numeral of higher value are added to the latter.

Thus, VI = 5 + 1, or 6; XI = 11; XV = 15; XVII = 17; CLXVI = 166.

3. A numeral placed before a numeral of higher value is subtracted from the latter.

Thus, IV = 5 — 1, or 4; IX = 9; XL = 40; XC = 90; XLVI = 50 — 10 + 5 + 1, or 46; XCVIII = 98.

4. A numeral placed between two higher numerals is always read in connection with the one which follows, and according to Rule 3, is subtracted.

Thus, XIV = 14; XXXIX = 39; LIV = 54; XLIV = 44; MDCCCLXXXIV = 1884; MDCCCVC = 1895.

Problems and Exercises.

33. Write the following expressions of volume as they should be written in a prescription:—45 minims, 6 fluid drachms, 14 fluid ounces, 3 pints, 1 gallon, $2\frac{1}{2}$ fluid ounces, 2 fluid drachms, and 30 minims.

Reduction Descending.

34. Reduce 2 Cong. 1 O. 2 f℥ 1 fʒ 20 ♏ to ♏.

Suggestion.—Reduce the 2 Cong. to O. by multiplying by 8; to the product add the 1 O. given; reduce the total number of O. to f℥ by multiplying by 16; add the 2 f℥ given; reduce f℥ to fʒ by multiplying by 8; add the 1 fʒ given; reduce fʒ to ♏ by multiplying by 60; finally add the 20 ♏ given.

35. Reduce 3 O. 5 f℥ to ♏. 36. Reduce 6 Cong. to f℥.

37. Reduce .67 Cong. to f℥. 38. Reduce $\frac{3}{17}$ Cong. to f℥.

Solution.—$\frac{3}{17} \times 8 \times 16 = \frac{384}{17}$ f℥ $= 22\frac{10}{17}$ f℥. [Since our measures are not graduated in fractions, it is customary to reduce fractions to lower units.—

$\frac{10}{17}$ f℥ $= \frac{10}{17} \times 8 = \frac{80}{17}$ fʒ $= 4\frac{12}{17}$ fʒ.
$\frac{12}{17}$ fʒ $= \frac{12}{17} \times 60 = \frac{720}{17}$ ♏ $= 42\frac{6}{17}$ ♏.
Then $\frac{3}{17}$ Cong. = 22 f℥, 4 fʒ, $42\frac{6}{17}$ ♏.

39. Reduce $3\frac{3}{8}$ f℥ to ♏.

40. How many fluid drachm doses in 2 pints and 12 fluid ounces of compound syrup of hypophophites?

REDUCTION ASCENDING.

41. How many fluid ounces in 6000 minims.

Solution.—In one fluid ounce there are 480 minims; hence there are as many fluid ounces in 6000 minims as 480 is contained in 6000.

42. How many pints in 64 fluid ounces?

43. How many gallons in 360 fluid ounces?

44. A physician wishes to write a prescription for 64 one-fluid-drachm-doses of elixir pepsin and bismuth. What volume should he prescribe?

45. How should the volume of 8000 ♏ be expressed in order that it might be measured with the customary measures?

46. Convert 666 fluid ounces into higher units—pints and gallons.

Solution.—Since there are 16 fluid ounces in a pint, $666 \div 16 =$ number of pints $= 41$ pints and 10 fluid ounces over. There being 8 pints in a gallon, $41 \div 8 =$ number of gallons $= 5$ gallons, and 1 pint over. The answer, therefore, is 5 gallons 1 pint 10 fluid ounces.

Remark.—Volumes in apothecaries' measure are expressed by compound denominate numbers rather than by simple denominate numbers with fractions—unless the fraction be $\frac{1}{2}$, in which case it may be used.

ADDITION.

47. Add the following volumes:—6 gallons; 4 gallons 3 pints 7 fluid ounces 5 fluid drachms; 3 pints 8 fluid ounces 4 fluid drachms.

Suggestion.—Arrange the denominate numbers under each other

so that each unit will form a separate column. Add the column of the smallest unit first. If the sum is larger than the equivalent of the next higher unit, reduce to that unit, but enter the remainder under the column added. Proceed in this way until all columns have been added.

Example.—	gallons	pints	fl. ounces	fl. drachms
	6	—	—	—
	+ 4	3	7	5
	+	3	8	4
	10	7	—	1

48. Add, 15 gallons 5 fl. ounces; 1 gallon 7 pints 12 fl. ounces; 5 fl. ounces 6 fl. drachms 45 minims; 10 fl. ounces 4 fl. drachms 30 minims.

SUBTRACTION.

49. Subtract 1 pint 12 fl. ounces from 5 gallons.

Suggestion.—Arrange subtrahend under minuend so that each unit of the former comes under the same unit in the latter;—i. e., gallons under gallons, pints under pints, etc. Subtract from right to left, that is, the lowest unit first, then the next higher, and so on. If then, in any column except the last one to the left, the subtrahend is found to exceed the minuend, one of the next higher unit in the minuend must be reduced.

Example:—	gallons	pints	fl. ounce.		gallons	pints	fl. ounce.
	5				4	7	16
	—	1	12	=	—	1	12
	4	6	4		4	6	4

50. A druggist taps a 36 gallon barrel of alcohol, making an air hole which he forgets to close. By keeping an account of the alcohol drawn off, he finds that the barrel supplied 31 gallons 4 pints 7 fl. ounces. How much was lost by evaporation?

MULTIPLICATION.

51. Multiply 5 pints 6 fl. ounces 2 fl. drachms 40 minims by 7.

Suggestion.—Multiply smallest unit first, then the next higher, and so on. In each case reduce the product to the next higher unit when that is possible, and write only the remainder under the unit multiplied.

Example.—	pints	fl. ounces	fl. drachms	minims
	5	6	2	40
				× 7
4 Cong.	5 O.	12 f℥	2 fʒ	40 ♏

40 ♏ × 7 = 280 ♏ = 4 fʒ and *40* ♏
2 fʒ × 7 = 14 fʒ; 14 fʒ + 4 fʒ = 18 fʒ = 2 f℥ and *2* fʒ
6 f℥ × 7 = 42 f℥; 42 f℥ + 2 f℥ = 44 f℥ = 2 O. and *12* f℥
5 O. × 7 = 35 O.; 35 O. + 2 O. = 37 O. = 4 Cong. and *5* O.

52. Multiply 1 gallon 3 pints 2 fl. drachms 40 minims by 8.

53. Multiply 600 ♏ by 20. Reduce product to higher units.

54. How much oil of cubeb is required to make 4 gross of 5 minim capsules?

Division.

55. Divide 10 gallons 5 pints 4 fl. ounces by 6.

Suggestion.—Divide from left to right, beginning with the highest unit. In case there is an indivisible remainder, reduce this to the next lower unit, and add to the number of that unit before the same is divided.

Example.—	gallons	pints	fl. ounces.
6)	10	5	4
	1	6	3 and 2 fʒ 40 ♏

10 Cong. ÷ 6 = 1 Cong. and 4 over; 4 Cong. = 32 O.; 32 O. + 5 O. = 37 O. 37 O. ÷ 6 = 6 O. and 1 over; 1 O. = 16 f℥; 16 f℥ + 4 f℥ = 20 f℥. 20 f℥ ÷ 6 = 3 f℥ and 2 f℥ over. 2 f℥ = 16 fʒ; 16ʒ ÷ 6 = 2 fʒ and 4 fʒ over. 4 fʒ = 240 ♏; 240 ♏ ÷ 6 = 40 ♏.

56. Divide 5 gallons 2 pints 2 fl. ounces by 8.

57. (a.) 3 O. ÷ 24; (b.) 4 Cong. ÷ 15; 4 f℥ ÷ 7.

58. With 8 fl. ounces 2 fl. drachms of oil of sandalwood in stock, how many 4 minim capsules could be filled?

59. (a.) How many 2 fl. drachm doses in an 8 fl. ounce mixture? (b.) How many 15 minim doses in 1 pint?

3. Imperial Measure.

This is the fluid measure of Great Britain. It has been in use since 1826, in which year it superseded the Wine Measure, which is now the customary fluid measure of *our* country.

The Imperial Measure is superior to the measure it displaced inasmuch as it bears a simple relationship to the system of weight official in that country, namely the avoirdupois weight (page 32).

The Imperial gallon, which is the primary unit, is defined as the volume of 10 av. pounds of pure water, at 62°F., and at a barometric pressure of 30 inches.

The Imperial fluid ounce is the volume of 1 av. ounce of pure water, at 62°F., and at a barometric pressure of 30 inches.*

Table A.

60 minims (♏) = 1 fluid drachm (fl. drm.)†
8 fluid drachms = 1 fluid ounce (fl. oz.)
20 fluid ounces = 1 pint (O.)
8 pints = 1 gallon (C.)

Table B.

Gallon.		*Pint.*		*Fl. Ounces.*		*Fl. Drachms.*		*Minims.*
1	=	8	=	160	=	1280	=	76800
		1	=	20	=	160	=	9600
				1	=	8	=	480
						1	=	60

*See foot note page 12.

†Observe that while the names of the units are the same as those of the Apothecaries' measure, the abbreviations are different.

Problems in Imperial Measure.

60. (a.) How many fl. oz. in 5 C.? (b.) How many fl. drm. in 5 O.*? (c.) How many ♏ in 2 fl. oz.?

61. Reduce 4 C. 3 O. 14 fl. oz. 2 fl. drm. to ♏.

62. Convert 5000 ♏ to higher units—fl. drm., fl. oz., etc.

63. Add 6 C. 4 O. 12 fl. oz.; 7 O. 10 fl. oz.; 3 fl. oz. 40 ♏

64. Subtract 5 fl. oz. 4 fl. drm. from 5 C.

65. Multiply 2 fl. oz. 4 fl. drm. 40 ♏ by 24.

66. Divide 3 O. by 48.

67. Divide 1 C. 2 O. 2 fl. oz. 3 fl. drm. by 16.

68. A Canadian druggist receives a 4 pint bottle of Eaton's syrup from a British drug firm. How many 4 fl. oz. bottles can he fill?

4. Avoirdupois Weight.

All weighable merchandize, except jewelry and precious stones*, are generally bought and sold in this country by avoirdupois weight,—the metric weight not having been adopted as yet for every-day commercial transactions.†

It should be distinctly understood that in the United States all drugs and chemicals which are not bought and sold by metric weight, are bought and sold by avoirdupois weight. The apothecaries' weight is *never* used in commercial transactions, not even in case of the most costly plant principles. An ounce bottle of morphine, or of quinine, contains $437\frac{1}{2}$ grains; an eighth ounce bottle of aconitine contains $\frac{1}{8}$ of $437\frac{1}{2}$ grains.

---

*O in this paragraph stands for Imperial pint.

*Sold by troy weight:—24 grains = 1 pennyweight; 20 pennyweights = 1 ounce; 12 ounces = 1 pound.

†To assist in popularizing the metric system, the firm of E. R. Squibbs & Sons has for several years put up their products in packages of metric quantities.

The avoirdupois system of weight was introduced into England about 600 years ago. It is now known in that country as the Imperial weight, and is used in prescription compounding as well as for buying and selling. It is the official weight of the British Pharmacopœia.

In the United States, the units of the avoirdupois weight are officially defined in terms of metric units. The smallest unit, the grain, is defined as equivalent to 64.7989 milligrammes.

Table A.

$437\frac{1}{2}$ grains (gr.) = 1 ounce (oz.)
16 ounces = 1 pound (lb.)

Table B.

Pound.		*Ounces.*		*Grains.*
1	=	16	=	7000
		1	=	$437\frac{1}{2}$

Note.—**The avoirdupois weight includes a unit called av. drachm, which is $\frac{1}{16}$ of an ounce, and is equivalent to $27\frac{11}{32}$ grains. But this unit is seldom used, it being customary to divide the ounce into halves, quarters, eighths, etc.**

Problems in Avoirdupois Weight.

69. (a.) Reduce 16 av. lb. to oz.; (b.) Reduce 4 lb. to gr.

70. (a.) How many grains in $\frac{1}{8}$ oz. of cocaine? (b.) How many grains in $\frac{1}{2}$ oz. bottle of atropine?

71. How many 1 oz. packages could be put up from a 25 lb. keg of sodium hyposulphite?

72. How many 3 gr. capsules could be filled from a 1 oz. bottle of quinine?

73. Aristol is listed at $1.75 per oz. What would be the cost of 1 ʒ in a prescription?

60 gr.

74. How many grains of cocaine hydrochloride would be left in a $\frac{1}{8}$ oz. bottle after removing 3 ss gr.

75. How many $\frac{1}{8}$ gr. morphine sulphate tablet triturates could be made from the contents of a $\frac{1}{8}$ oz. bottle?

76. Reduce 50000 gr. to lb. and oz.

77. Reduce 35000 gr. to lb.

78. Reduce 3000 gr. to oz.

79. A druggist desires to put up 5 gross of 10 gr. powders of Compound Acetanilid Powder (N. F.). How much of the latter must be made for the purpose?

80. 15 lb. 6 oz. + 6 lb. 10 oz. 100 gr. + 11 oz. 400 gr.

81. From a 5 lb. can of opium the following quantities have been removed:—3 oz., $1\frac{3}{4}$ oz., 1.64 oz., 175 gr. How much remains?

82. The British Pharmacopœia gives the following formula for Gregory's powder: Rhubarb, 2 oz.; Light Magnesia, 6 oz.; Ginger 1 oz. How many 20 gr. doses would this make?

5. Apothecaries' Weight.

This is a modification of the old English troy weight (See note page 32, and note page 35), the two being the same except in the units between the ounce and the grain.

The apothecaries' weight has never received legal recognition in this country; but since the apothecaries' grain is identical with the avoirdupois grain, and the latter is now defined in metric units based on the National Prototype Kilogramme, this reference standard may serve also for the apothecaries' system.

The smallest unit—the grain—was originally derived from

the average weight of a grain of wheat*. Later the weight of a certain volume of water [1 cu. in. of water, in vacuo, and at 62° F = 252.75965 gr.] was used as the basis of weight units in England; but the name *grain* for the smallest unit of weight has been retained to this day.

When the Pharmacopœia of London was compiled (in 1618), the troy (apothecaries') weight was decided upon as the weight to be used in compounding medicines. In England it has since been superseded by the Imperial weight (avoirdupois); but in this country the apothecaries' weight is so firmly established, that the inconveniences incident to the use of one system of weight for compounding, and a different system for buying and selling, will, no doubt, continue to trouble the pharmacist for many years to come.

Table A.

20 grains (gr.)	= 1 scruple (℈)
3 scruples	= 1 drachm (ʒ)
8 drachms	= 1 ounce (℥)
12 ounces	= 1 pound (℔)

Table B.

℔	℥	ʒ	℈	gr.
1 =	12 =	96 =	288 =	5760
	1 =	8 =	24 =	480
		1 =	3 =	60
			1 =	20

*In 1266, in the reign of Henry III, the following law was enacted:—"An English silver penny, called a sterling, round and without clipping, shall weigh 32 grains of wheat, well dried and gathered out of the middle of the ear; and twenty pence (pennyweights) do make an ounce, and twelve ounces a pound." Subsequently, in the reign of Henry VII, about 1497, the pennyweight was divided into 24 parts, called grains, in place of into 32; thus creating the system of troy weight as used to this day.

Note.—(1.) The apoth. pound is seldom used in pharmacy.

(2.) The troy grain, apoth. grain, and the avoirdupois grain are identical.

(3.) The apoth. ounce, and the troy ounce are the same, but the av. ounce is 42½ gr. smaller.

(4). The apoth. pound and the troy pound are the same, but the av. pound is 1240 gr. larger.

Apothecaries' Weight in Prescriptions.—Roman numerals are used; and the numbers always follow the symbols or abbreviations.

In case of fractions, with the exception of $\frac{1}{2}$, expressed by ss [abbr. for semis = one-half], Arabic numerals are used.

Example:

℞	Acidi Arsenosi	gr. $\frac{1}{5}$
	Strychninæ Sulphatis	gr. $\frac{1}{5}$
	Quininæ Sulphatis	℈ ij
	Ext. Gentianæ	ʒ ss
	Ft. pil. no. xx	

Problems in Apothecaries' Weight.

83. Reduce 4 ℥ 2 ʒ 1 ℈ to gr.

84. Reduce 7000 gr. to higher units—℈, ʒ, ℥ and ℔.

85. (a.) Reduce 1000 gr. to ʒ; (b.) 7000 gr. to ℔.; (c.) 2000 gr. to ℥; (d.) 437½ gr. to ℥.

86. A certain formula for a horse powder is as follows :

Black Antimony	℥ viij
Sulphur	℥ vj
Saltpetre	ʒ vj
Resin	ʒ v
Capsicum	ʒ iij ℈j

How much will the formula make?

87. Subtract 2 ʒ 1 ℈ 12 gr. from 8 ℥.

88. The following prescription is to be filled, making eight (8) times the quantity :

℞	Ext. Ergotæ	ʒ j
	Ferri Sulphatis	℈ jss
	Ext. Nucis Vomicæ	gr. viij
	Hydrarg. Chlor. Corr.	gr. ss
	Make 30 pills.	

How much of each ingredient must be weighed out?

89. Divide 1 ℥ 2 ʒ 1 ℈ 10 gr. by 8; (b.) by 80; (c.) by 800.

90. Divide 1 ℥ 4 ʒ by $\frac{3}{4}$; (b.) by $\frac{2}{13}$; (c.) by 1.034; (d.) by .0055.

91.	℞	Zinci Phosphidi	℈ ij
		Ext. Nucis Vomicæ	ʒ j
		Ext. Gentianæ	ʒ iv
		Make 80 pills.	

How much of each ingredient in each pill?

92.	℞	Camphoræ	gr. lxv
		Ammonii Carbonatis	gr. xlviij
		Pulv. Opii	gr. ix

Mix and divide into 3 gr. doses.
How many will it make?

93.	℞	Rhei	ʒ ij
		Aloes	ʒ iss
		Myrrhæ	ʒ j
		Saponis	ʒ j
		Olei Menthæ Piperitæ	♏ viij
		Glucosi	ʒ j ℈ j

Mix and divide into 4 gr. pills.
How many should be made?

94. ℞ Make 48 pills each to contain

Atropine	$\frac{1}{75}$
Morphine	$\frac{1}{8}$

Excipient q. s. to make a 2 gr. pill.

Note.—Since $\frac{48}{75}$ gr. of atropine cannot be weighed, proceed as follows:—Weigh out 1 gr. of atropine and mix with 74 gr. of some inert powder, thus making 75 gr. of mixture, of which each gr. represents $\frac{1}{75}$ gr. of atropine. Now weigh out 48 grains of this mixture—the amount containing $\frac{48}{75}$ gr. of atropine.

This rule can also be applied in case of solutions. Suppose $\frac{1}{100}$ gr. of strychnine sulphate is to be contained in each fluid drachm of a 4 fluid ounce preparation. In 4 fl. ounces there are 32 fluid drachms; hence $\frac{32}{100}$ gr. of strychnine sulphate is required—an amount which cannot be weighed. Proceed thus:—weigh out 1 gr. of strychnine sulphate and dissolve in enough water to make 100 minims. Each minim of this solution contains $\frac{1}{100}$ gr. of strychnine sulphate; therefore 32 minims should be used in the prescription.

CHAPTER II.

Relationship of Systems.

1. Metric and English Linear Measures.

The official equivalents are:

1 M = 39.37 in.,* or 1.093611 yds.

[It follows that — 1 dm. = 3.937 in., 1 cm. = .3937 in., 1 mm. = .03937 in.]

1 in. = 25.4001 mm.
1 ft. = .304801 M.
1 yd. = .914402 M.

While but one connecting link is necessary, the others are of great convenience, as the labor of "figuring" may be lessened by their use,—just as in a city many steps may be saved by having more than one bridge across the river.

In many cases, where great accuracy is not required, the official equivalents may be rounded off to less cumbersome numbers.

For instance: — 1 in. = about 25 mm.
1 ft. = about .3 M.

These approximate equivalents should be memorized. They are sufficiently accurate for converting into English measure the dimensions of drugs (roots, leaves, barks, etc.) given in metric terms in the U. S. Pharmacopœia. They can be used also in "translating" the size of filter-paper, funnels, plasters, etc.

*** According to Capt. A. R. Clark, who made the determination for the British Government, the equivalent is — 1 M = 39.370432 in.; but the official equivalent given above is sufficiently accurate for all practical purposes.**

Problems.

Use official equivalents.

95. Reduce 69.325 M. to in.

Solution.—If 1 M. = 39.37 in., then 69.325 M. will equal 69.325 × 39.37 in. = 2729.3 in.

96. Reduce 69.325 in. to M.

Solution.—If 1 M. = 39.37 in., then 69.325 in. will equal as many M. as 39.37 is contained in 69.325.

$$69.325 \div 39.37 = 1.684 \text{ [M.]}$$

97. (a.) Reduce $60\frac{1}{2}$ yd. to M.; (b.) $54\frac{3}{4}$ ft. to M.

98. Reduce 4 yd. 2 ft. $7\frac{1}{2}$ in. to M.

Suggestion.—Reduce first to in.; then to M.

99. (a.) Reduce 25 cm. to in.; (b.) 56 cm. to ft.

100. Reduce 154 mm. to in.

101. A certain tube has an inside diameter of $\frac{3}{16}$ in. Give this in mm.

102. The tube is 4 ft. 8 in. long. Give length in M.

Use Approximate Equivalents.

103. Aconite is described in the U. S. P. as being 10 to 20 mm. thick, and from 50 to 75 mm. long. Give its dimensions in inches.

104. Viburnum Opulus is from 1 to 1.5 mm. thick, and about 30 cm. long. Give its dimensions in inches.

105. Swedish filtering paper is kept in the laboratory in the following diameters: 5.5 cm., 7 cm., 9 cm., 12.5 cm., 15 cm., 18.5 cm., 24 cm., 38.5 cm. Give these sizes in inches.

106. A druggist receives a prescription for a capsicum plaster 8 cm. by 12 cm. Give size in inches.

107. A druggist orders a 5 in. funnel (diameter across top); but the jobber sends a 12 cm. funnel. Is the one sent ırger or smaller than the one ordered? How much?

2. Metric and Apothecaries' Fluid Measures.

The official equivalents are:

1 c.c. (or ml.) = 16.23 ♏
1 L. = 33.814 f℥
1 f℥ = 29.57 c.c. *
1 Cong. = 3.78543 L.

For calculating doses, and for all pharmaceutical work not requiring very great accuracy, the following approximate equivalents may be used:

1 c.c. = 16 ♏
1 f℥ = 30 c.c.

Problems.

Use Official Equivalents.

108. Reduce 3 pints to c.c.
Solution.—3 pints = 48 f℥; $48 \times 29.57 = 1419.36$.
Hence 3 pints = 1419.36 c.c.

109. Reduce 1 Cong. 2 O. 6 f℥ to c.c.
Suggestion.—Reduce to f℥; then to c.c.

110. (a.) Reduce 93.29 c.c. to ♏; (b.) $9\frac{7}{19}$ c.c. to ♏.

111. Reduce (a.) 2 L. to pints; (b.) 5 Kl. to Cong.

112. Reduce (a.) 300 ml. to pints; (b.) 3.786 L. to pints.

113. Reduce (a.) $9\frac{7}{19}$ c. c. to f℥; (b.) $2\frac{2}{11}$ c.c. to ♏.

114. Reduce (a.) 4.5 ml. to ♏; (b.) 4.5 c.c. to ♏.

115. Reduce (a.) $40\frac{3}{4}$ ♏ to c. c.; (b.) 10 f℥ to c.c.

---

*More accurately, 29.5737 c. c.

116. How many f℥ will a 500 c.c. flask hold?

117. How many c.c. will a pint bottle hold?

Use approximate equivalents.

118. Express the following doses in metric measure: (a.) croton oil, 1 — 2 ♏; (b.) tr. belladonna, 5 — 15 ♏. (c.) infusion buchu, 1 — 2 f℥; (d.) tr. cinchona, 1 fʒ.

119. Express the following formula in apoth. measure:

Castor oil	75 c.c.
Mucilage of acacia	37.5 c.c.
Orange flower water	25 c.c.
Cinnamon water	62.5 c.c.

120. Express in metric measure the following formula for a cough medicine:

Tr. Opium	fʒ vj
F. E. Ipecac	fʒ j
F. E. Sanguinaria	fʒ j
Syr. Squill	f℥ iij
Syr. Wild Cherry	f℥ ix
Syr. Tar q. s.	O j

121. Express the following doses in cubic centimeters: — antiperiodic tincture (N. F.), 1 — 4 fʒ; tr. opium, 5 — 20 ♏; syr. lactucarium, 2 — 8 fʒ; fl. ext. convallaria, 3 — 20 ♏.

122. Express the following doses in apothecaries' measure: — sol. potass. arsenite, 0.3 c.c.; sol. potass. citrate, 15 c.c.; fl. ext. ipecac, 0.9 — 1.9 c.c.; spt. glonoin, 0.06 — 0.12 c.c.; tr. gelsemium, 0.6 — 1.25 c.c.; comp. decoction of sarsaparilla, 120 — 180 c.c.; inf. cinchona, 30 c.c.; oil of eucalyptus, 0.6 — 0.9 c.c.; syr. of tar, 3.7 — 7.5 c.c.

123. A druggist receives four "metric prescriptions": the first for a 60 c.c. solution, the second for a 120 c.c. lini-

ment, the third for a 360 c.c. emulsion, the fourth for a 15 c.c. eye wash. State in fluid ounces the size of the bottle to be selected in each case.

Note.—**American-made prescription bottles are commonly gauged in fluid ounces.**

3. Apothecaries' and Imperial Measures.

The Imperial measure differs from our apothecaries' measure in two respects:—the Imperial minim equals but 0.96014 ♏ (U. S.); and the Imperial pint is divided into 20 Imperial ounces, while the pint (U. S.) contains only 16 f℥ (U. S.)

The equivalents usually employed, are:

1 Imperial minim = .96 ♏ (U. S.)
1 Imperial fluid drachm = .96 fʒ (U. S.)
1 Imperial fluid ounce = .96 f℥ (U. S.)

1 Imperial pint = 1.2 O. (U. S.) [accurately, 1.20017501]
1 Imperial gallon = 1.2 Cong. (U. S.) [accurately, 1.20017501].

124. Convert 6 fl. oz. Imp., into f℥, U. S.

Solution.—1 fl. oz. = .96 f℥. And 6 × .96 = 5.76.

Therefore 6 fl. oz. = 5.76 f℥.

But since our customary measures are not graduated in decimal fractions of each unit, convenience in measuring requires that such decimal fractions be reduced, so as to express the amount in integers of a lower unit (denomination). Hence .76 f℥ should be reduced to fʒ; and should there be a fractional fʒ in the product, this fractional fluid drachm should be reduced to minims.

.76 × 8 = 6.08. Hence .76 f℥, = 6 fʒ and .08 fʒ; and since .08 × 60 = 4.80, .08 fʒ = 4.8 ♏.

Then 5.76 f℥ = 5 f℥, 6 fʒ, 4.8 ♏.

125. Convert 6 f℥ into Imperial measure.

126. Convert 1 Imperial pint into pints, f℥, fʒ and ♏ of U. S. measure.

127. Convert 3 Imperial pints into Apothecaries' measure.

128. Convert 3 pints, U. S. into Imperial measure.

129. Convert 6 pints 6 fluid ounces 6 fluid drachms Imp., into U. S., apothecaries' measure.

Suggestion.—Reduce to fluid drachms before converting into U. S. measure. And should the final answer contain a fraction of a drachm, reduce this to minims.

130. Convert O. ii f℥ vii fʒ iii ♏ xv into Imperial measure.

131. Convert the Imperial measures in the following Canadian prescription into U. S. apoth. measure :

Liq. Ext. Bellad.	10 fl. oz.
Camphor	1 oz.
Dist. Water	2 fl. oz.
Alcohol q. s.	20 fl. oz.

Note. If the ingredients were all liquids, it would be allowable to read f℥ in place of fl. oz. A somewhat larger volume of liniment would be dispensed in that case, but the relative proportions of the ingredients would not be changed. In the presence of solids, however, it is different; for the relationship between the Imperial ounce and the Imperial fluid ounce on the one hand, and the apoth. ounce and the apoth. fluid ounce on the other, is not the same. See page 31 and page 63. However, the difference is so small that it is usually ignored.

4. Metric and Imperial Measures.

The following equivalents may be used:

1 Imp. fl. oz. = 28.39 c. c.

1 c. c. = 16.9 ♏ (Imp.)

But the equivalents are seldom required and need not be memorized. Should it be necessary to convert metric measure into Imperial, or *vice versa*, and the equivalents are not at hand, convert the measure given to apothecaries' and this to the measure required, as indicated under problems # 133 and # 134.

133. Convert 8 fl. oz. (Imp.) into c.c.

Solution.—8 × .96 = 7.68. ∴ 8 fl. oz. = 7.68 f℥.
7.68 × 29.57 = 227. ∴ 7.68 f℥ = 227. c.c.
134. Convert 500 c.c. into fl. oz.

Process.—500 ÷ 29.57 = number of f℥.
Number of f℥ ÷ .96 = number of fl. oz.
135. Convert 40 ♏ (Imp.) into c.c.

136. Convert 1 L. into Imperial measure—pints, fluid ounces, etc.

137. Convert 50 gallons (Imp.) into Liters.

Note.—The sign ∴ stands for then, hence, or therefore.

Approximate Measures Used in the Administration of Medicine.

The following domestic measures are in common use:

1 Tumblerful = 8 f℥ = nearly 240 c.c.
1 Teacupful = 4 f℥ = nearly 120 c.c.
1 Wineglassful = 2 f℥ = nearly 60 c.c.
1 Tablespoonful = 4 fʒ = nearly 15 c.c.
1 Dessertspoonful = 2 fʒ = nearly 7.5 c.c.
1 Teaspoonful = 1 fʒ = nearly 3.75 c.c.
1 Drop (watery liquids) = 1 ♏ = 0.06 + c.c.
1 Drop (alcoholic liquids) = ½ ♏ = 0.03 + c.c.

It has been pointed out time and again by pharmaceutical writers that the capacity of the common tablespoons is not

4 f ʒ, but over 5 f ʒ; that dessertspoons hold between 3 and 3½ f ʒ; and that teaspoons which hold less than 1½ f ʒ, are rare indeed.

It should also be remembered that the drop is not a definite volume, and that it seldom measures exactly 1 ♏, even in case of pure water. The size of the drop is dependent not only on the nature of the liquid, but is influenced also by the temperature, and by the size and shape of the mouth of the vessel from which the drop is emitted. In case of medicine droppers, (which are much used in prescription work), the drop varies directly with the *outside* diameter of the lower extremity of the tube.

While the drop is not a definite volume, it is, however, considered by most physicians to be sufficiently definite for the purposes of practical medicine; and the old table-, dessert- and teaspoon-equivalents are still generally used as the basis of dose calculations, regardless of the fact that the spoon manufactures have increased the capacity of spoons over 50%.

Problems.

Use the equivalents in the table.

138. Write a prescription for 32 teaspoonful doses, each to contain 1½ ♏ of tincture of aconite, and enough compound elixir of taraxacum to make the proper volume.

139. ℞	Antim. et Potass. Tart.	gr. iv
	Liq. Amm. Acet.	f ℥ iv
	Spt. Aeth. Nit.	f ℥ ij
	Tr. Aconiti.	f ʒ j
	Syr. q. s.	f ℥ viij

Teaspoonful 3 times a day.

Calculate the single dose for the first four ingredients.

140. Formula for artificial Hunyadi Water:

Magnesium Sulphate	
Sodium Sulphate of each	℥ s.s.
Potassium Sulphate	gr. ij
Sodium Chloride	℈ j
Water q. s.	f℥ viij

Calculate the amount of each salt in a wineglassful, which is the usual dose.

141. ℞

Tincturae Veratri Viridis	3	5
Spiritus Aetheris Nitrosi	30	
Liquoris Potassii Citratis	20	
Syrupi Zingiberis q. s.	240	

Calculate the amount of each of the first three ingredients in a tablespoonful dose.

142. Write a metric prescription for 8 wineglassful doses, each to contain 0.5 c.c. of tincture nux vomica, and enough compound infusion of gentian (Br.) to make the proper volume.

143. ℞

Ac. Hydrocyan. Dil.	f ʒ ij
Aq. Amygd. Amar. q. s.	f ℥ iv
Teaspoonful.	

(a.) How much dilute hydrocyanic acid in each f ʒ dose?

(b.) How much of the acid would be administered for a dose if a common teaspoon, holding 100 ♏, were used?

Metric and Apothecaries' Weights.

Official Equivalents.

1 gr. = 64.79 mg. [but 64.8 would be nearer correct.*]
1 ℥ = 31.1035 Gm.
1 Gm. = 15.4324 gr. [accurately, 15.43235639 gr.]

*The accurate equivalent is 64.7989 mg.

Approximate Equivalents.

1 gr. = 65 mg., or .065 Gm.
1 ℥ = 31 Gm.
1 Gm. = 15.4 gr.

In reducing gr. to Gm., use the equivalent, 1 gr. = .065 Gm., rather than the equivalent, 1 Gm. = 15.4 gr. For multiplication involves less work than does the process of division.

For computing doses, the equivalent, 1 gr. = 65 mg., is sufficiently accurate, and is generally used.

Problems.

Use Official Equivalents.

144. (a.) Convert 7 ℥ into Gm.; (b.) 150 gr. into Gm.

145. (a.) Convert 6 ℥ 2 ʒ 1 ℈ 12 gr. into Gm.

146. (a.) Convert $\frac{3}{16}$ gr. into mg.; (b.) 6.4 gr. into mg.

147. (a.) Convert 6.4 mg. into gr.; (b.) 6.042 Gm. into gr.

148. Convert 200 Gm. into apoth. units.

Use Approximate Equivalents.

149. (a.) Convert 500 Gm. into ℥. (b.) Reduce fraction in answer to gr.

150. Convert 500 Gm. into gr.

151. Explain why answer to 150 is not equal to answer to 149 (a) × 480.

152 and 153. Give the following doses in metric weight: Arsenous acid. $\frac{1}{30}$ — $\frac{1}{15}$ gr.; atropine, $\frac{1}{100}$ — $\frac{1}{60}$ gr.; ext. belladonna leaves, $\frac{1}{6}$ — $\frac{1}{2}$ gr.; ext. rhubarb, 1 — 10 gr.; ferric citrate 3 — 20 gr.; salol, 5 — 30 gr.; sodium salicylate,

5 — 60 gr.; cascara sagrada, 15 — 60 gr.; coca, ¼ — 2 ʒ; Rochelle salt, 1 — 8 ʒ.

154. ℞. Bismuthi Subcarb. ʒ iij
Morphinæ Sulph. gr. j
Pulv. Aromat. ʒ j
Make 12 powders.

(a.) Convert to metric weight. (b.) How many mg. of morphine sulphate in each dose?

155. Express the quantities in the following formula for worm troches, in metric weight:

Res. Podophyllum	gr. iv
Santonin	gr. x
Powd. Rhubarb	gr. xv
Milk Sugar	ʒ ss

Mucilage of Tragacanth q. s. to mass.
Make 15 troches.

156. Express the following doses in apothecaries' weight: Aconitine, .0001 Gm.; hyoscyamine sulphate, .0008 Gm.; ipecac (as emetic), 1.4 Gm., jalap, .65 — 1.3 Gm.; ext. nux-vomica, .008 — .016 Gm.; antimonial powders, .2 — .52 Gm.; quinine sulphate, .065 — 1.5 Gm.; effervescent magnesium sulphate, 7.77 — 31.1 Gm.

157. Express the quantities in the following prescription in apothecaries' weight:

℞	Quininæ Sulphatis	3	25
	Strychninæ Sulphatis		065
	Ferri Phosphatis	6	50

Make 50 pills.

7. Metric and Avoirdupois Weights.

Official Equivalents.

1 gr. = 64.79* mg. (or .06479 Gm.)
1 oz. = 28.35 Gm.
1 lb. = 453.592 Gm. (accurately, 453.592653 Gm.)
1 Gm. = 15.4324 gr.
1 Kg. = 2.2 lb. (accurately, 2.20462 + lb.

Note.—The metric pound, used in commerce, is 500 Gm., or ½ Kg. It is equivalent to 1.1 av. lb.

Approximate Equivalents.

1 gr. = 65 mg.
1 oz. = 28⅓ Gm.
1 lb. = 454 Gm.
1 Gm. = 15.4 gr.
1 Kg. = 2.2 lb.

Problems.

Use Official Equivalents.

158. Convert 5 oz. into Gm.

159. Convert 5 lb. into Gm.

160. Convert 5 lb. into Kg.

161. Convert 5 lb. 5 oz. 200 gr. into Gm.

162. Convert 60 Gm. into gr.

163. Convert 600 Gm. into oz.

164. (a.) Convert 6 Kg. into lb. (b.) Convert 6 metric pounds into lb.

165. Convert 5675.45 Gm. to avoir. weight.

---

* The accurate equivalent being 64.7989 mg., 64.8 mg would be nearer correct than 64.79, as given in the table.

166. Express the quantities in the following formula for menthol plaster in metric weight :

Menthol	2 oz.
Yellow Wax	2 oz.
Resin	1 oz.
Lead Plaster	15 oz.

Use Approximate Equivalents.

167. (a.) Convert 5 lb. into Gm. (b.) Convert 5 oz. into Gm. (c.) Convert 5 gr. into mg. (d.) Convert 50 Gm. into gr.

168. Convert the quantities in the formula for compound cathartic pills into avoirdupois weight:

Comp. Ext. Colocynth	800 Gm.
Mild Mercurous Chloride	600 Gm.
Ext. Jalap	300 Gm.
Gamboge	150 Gm.

169. A druggist buys the following list of goods from E. R. Squibb & Sons :

5 Kg.	Powd. Acacia.
$\frac{1}{2}$ Kg.	Iodoform.
2 Kg.	Ether.
100 Gm.	Lithium Citrate.
25 Gm.	Amyl Acetate.
500 Mg.	Aconitine.

(a.) Convert these weights into avoirdupois.

(b.) Box and packing being figured at 8 Kg., how much would the gross weight be in avoir. weight ?

AVOIRDUPOIS (OR IMPERIAL) AND APOTHECARIES' WEIGHTS.

Equivalents:

1 gr. apoth. = 1 gr. av. or Imp.
1 ℥ = 1.1 oz. av. or Imp. (accurately, 1.097143).

Note.—Since the grain apoth. is identical with the grain avoir., any weight in one of these systems can be converted into weight in the other, by reducing to grains, and then to the higher units of that other system.

Thus, 6 ℥ = 2880 gr. = 6 oz. 255 gr.
6 oz. = 2625 gr. = 5 ℥, 3 ʒ, 2 ℈, 5 gr.

To use the equivalent, 1 ℥ = 1.1 oz. would be practically no shorter (since the fraction would have to be reduced to smaller units), and the answer would be only approximately correct.

Problems.

170. (a.) Convert 2 ℥ into avoir. weight.
(b.) Convert 15¼ ℥ into avoir. weight.

171. (a.) Convert 15 ℥ 3 ʒ 2 ℈ 10 gr. into avoir. weight.
(b.) Convert 3 ℥ 2 ʒ 1 ℈ 15 gr. into Imp. weight.

172. ℞ Ext. Stramonii ʒ ij
Adipis Benz. ℥ ij

Express quantities in avoir. weight.

Note.—Ointments, dusting powders, etc., are usually prescribed in quantities of 1 ℥ or more. But the 2 ʒ weight is the largest in the common set of prescription weights, and in many stores larger apoth. weights are not at hand. The proper procedure then is to reduce the apoth. weight to avoir. weight, in order that the counter weights, which are avoir., may be utilized. For instance, 2 ℥ of petrolatum is to be weighed. 2 ℥ = 2 oz. and 85 gr. So the 2 oz. weight of the counter set is used, together with a 1 ʒ weight, a ½ ℈ weight, and a 5 gr. weight of the prescription set. To weigh out 1 oz. when 1 ℥ is prescribed, involves a change in proportion of active medicine to base or diluent—a change which the pharmacist is not justified in making, except with the consent of the physician.

173.	℞	Sodium Sulphate	℥ iij
		Sodium Chloride	℥ viij
		Linseed, powd.	℥ viij

Suppose av. oz. were weighed in place of the apoth. ounces. How much difference would it make in the weight of the mixture?

Note.—In this prescription the ℥ is the only unit used. And should avoir. ounces be dispensed in place of apoth. ounces, the proportions would not thereby be changed. There would still be 3 parts of sodium sulphate to 8 parts of the other ingredients. So there could be no serious objection to such a change.

174. (a.) Convert 3 oz. av. into apoth. weight.
(b.) Convert 5 oz. Imp. into apoth. weight.
(c.) Convert 3 oz., 300 gr. into apoth. weight.
(d.) Convert 7 $\frac{11}{17}$ oz. into apoth. weight.

175. A pharmacist dispenses ʒ iv of aristol from a 1 oz. package. How many grains remain? How many ʒ?

176. How many 1 ℈ doses of bismuth sub-nitrate could be dispensed from a 4 oz. package of the salt?

CHAPTER III.

VOLUMES AND WEIGHTS.

A. Specific Gravity (Relative Density, Specific Weight.)

By weighing equal volumes of various substances the fact is made apparent that hardly two substances can be found which weigh exactly alike volume for volume. Gold weighs more than twice as much as copper. Glycerin weighs one and one-fourth as much, volume for volume, as water. Ether is not quite three-fourths as heavy as water. Mercury is nearly twenty-three times as heavy as lithium, but not quite twice as heavy as iron. Thus the relation between weight and volume differs with nearly every substance, but is always (under like conditions) the same for the same substance. This being true, density (a term expressing relation of weight to volume) serves as a characteristic, as an "ear-mark," by which substances may be identified, or their purity be determined.

The most convenient way of expressing the density of a substance is by comparison with the density of another substance. The standard selected for such comparisons, for solids and liquids, is pure water*, the density of which is taken as unity—as 1.000. The density of any substance twice as heavy as water may then be expressed by 2.000; the density of a substance one-half as heavy as water, by .5; —these numbers indicating not weights, but ratios between weights.

---

* For gases, hydrogen at 0°C is taken as the standard of density.

When density is thus expressed (by comparison), it is properly called *relative density;* but its synonym, specific gravity, is more generally used, and will be used in the succeeding pages.

To repeat: Density is the relation which the weight of a body bears to its volume. Specific gravity is the density of a body as compared with the density of water, or with some other arbitrarily established standard.

Since the volume, and hence the density, of a body varies with the temperature, it is necessary to have a standard temperature for specific gravity determinations. The temperature adopted by the U. S. Pharmacopœia is 15° C., both for the standard—water—and for the substance of which the specific gravity is to be determined. This is expressed by $\frac{15^\circ \text{ C.}}{15^\circ \text{ C.}}$

In Europe it is customary to make the determination at [or near] 15° C., but to compare with water at 4° C., the temperature at which water reaches its greatest density. These temperatures are expressed by $\frac{15^\circ \text{ C.}}{4^\circ \text{ C.}}$

Calculating Specific Gravity.—The data required are:—the weight of the body, and the weight of an equal volume of water.

In case of liquids, a small bottle is completely filled with water at the proper temperature, and weighed. Then the same bottle is filled with the liquid, and the weight determined. In each case the weight of the bottle itself is subtracted, giving in the latter case the net weight of the liquid, and in the first case, the net weight of an equal volume of water.*

The specific gravity of a solid, in mass, is found as follows:—The body is weighed in air, then in water, being suspended in the latter by a hair. In water the body is

---

See next page for foot note.

found to weigh less than in air. The difference betw two weights, i. e., the loss, is due to the buoyant force water, and this is exactly equal to the weight of just as m water as the body displaces. In other words, the l exactly equal to the weight of an equal bulk of water.

Note.—If the solid is soluble in water, other liquids must be in place, and this taken cognizance of in the calculation.

If the solid is lighter than water, a sinker is used to make complete immersion possible.

If the solid is a fine powder, a definite weight of it is dropped into a definite volume of water, and the increase in volume noted

[Laboratory directions are omitted from this volume, but a given in Sturmer and Vanderkleed's Course in Quantitative Analysis.]

Calculation.—To find the specific gravity of a body di its weight by the weight of an equal volume of water.

---

* HYDROMETERS.

These are floats or buoys which indicate the sp. gr. of a liquid by the dept to which they sink. The graduated scale on a modern hydrometer indicates th sp. gr. directly. But the older instruments carry arbitrary scales, some o which (notably those of Beaumè) are still in use.

BEAUMÈ SCALE.

There are two scales—one for liquids lighter than water, and one for liquids which are heavier. The degrees on the scale for liquids heavier than water can be reduced to sp. gr. by the following rule:

145 ÷ (145 — degrees Beaumè) = sp. gr.

Problem.—A certain hydrochloric acid is marked 20°B. What is its sp gr.?

Solution.—145 ÷ (145 — 20) = 145 ÷ 125 = 1.16 sp. gr.

For liquids lighter than water the scale runs in the opposite direction, it zero indicating the density of a 10% salt solution, and the degrees increasing as the density decreases. The rule for reducing degrees Beaumè for liquids lighter than water to sp. gr. is:

140 ÷ (130 + degrees Beaumè) = sp. gr.

Problem.—Ammonia water, marked 26°B., has what sp. gr.?

Solution.—140 ÷ (130 + 26) = 140 ÷ 156 = .8974°B.

PROBLEMS.

Reduce to sp. gr. the following degrees B. on scale for liquids heavier than water:—(a.) 0°B.; (b.) 25°B.; (c.) 30°B.; (d.) 50°B.

Reduce to sp. gr. the following degrees B. on scale for liquids lighter than water;—(a.) 18°B.; (b.) 30°B.; (c,) 40°B.; (d.) 50°B.

$$\text{Sp. gr.} = \frac{\text{weight of body}}{\text{weight of equal bulk of water}}$$

pı ... it... ...tions in the quotient are stated as decimals; and in I... ...ese are interminate, they are usually carried to the ... place.

...r example:—weight of body = 2 Gm.; weight of equal ...ume of water = .6 Gm. Then $\frac{2 \text{ Gm.}}{.6 \text{ Gm.}} = 3.333$ (Sp. gr. of body.)

In practice the *weight of equal bulks of water* is not directly ...terminable in all cases, but must frequently be found by ...culation from other (determinable) data, before the fore...ng rule can be applied. [For problems of this kind see ...mer and Vanderkleed's Course in Quantitative Analysis.]

Problems.

177. A certain bottle is found to hold 96.54 Gm. of water. ...f a certain oil the bottle holds 94.78 Gm. What is the sp. ...r. of the oil?

94.78	÷	96.54	= .981
wt. of body of oil	÷ wt. of	equal bulk of water	= sp. gr.

178. A certain fragment of ore weighs 5.4 Gm. in air. ...uspended in water [from the arm of a balance] it weighs ...01 Gm. Calculate the sp. gr. of the ore.

Solution:— 5.4 Gm. (wt. in air)
— 4.01 Gm. (wt. in water)

1.39 Gm. (loss wt. in water, hence wt. of equal bulk of water)

Then— 5.4 Gm. ÷ 1.39 Gm. = 3.884 (sp. gr.)

179. A certain bottle holds 500 Gm. of water. Of a cer-

tain solution it holds 650 Gm. Calculate the sp. gr. of the solution.

180. A certain piece of metal weighs 10.10 Gm. in air, and 8.65 Gm. suspended in water. What is the sp. gr. of the metal?

181. A certain iron cylinder holds 50 lb. of mercury. Of water it hold 3.69 lb. What is the sp. gr. of mercury?

182. What is the sp. gr. of a crystal which weighs 2.34 Gm. in air, and 1.18 Gm. suspended in water?

183. A certain bottle holds 245 gr. of water. Of oil of peppermint it holds 220.5 gr. What is the sp. gr. of the oil?

184. A certain bottle holds 3 oz. (av.) of water. Of nitric acid the same bottle holds 120.2607 Gm. What is the sp. gr. of the nitric acid.

Note: When a denominate number is to be divided by another denominate number, both must be in the same unit (denomination).

Specific Volume.

Specific volume expresses the same fact expressed by specific gravity; namely, the density of a body as compared with the density of water.

To find the specific gravity, the weight of a body is compared with the weight of an equal volume of water. To find the specific volume, the volume of a body is compared with the volume of an equal weight of water. Specific volume is, therefore, the reciprocal of specific gravity. The greater the specific gravity of a body, the smaller is its specific volume; and vice versa.

Specific volume is not generally used.

Calculating Specific Volume.—Divide the volume of the body by the volume of an equal weight of water.

$$\text{Sp. V.} = \frac{\text{vol. of body}}{\text{vol. of equal wt. of water.}}$$

Fractions in the quotient are expressed in decimals, and are carried to the third place, as a rule.

185. A certain weight of oil measures 60 c. c. The same weight of water measures 52 c. c. What is the specific volume of the oil?

60 c.c.	÷	52 c.c.	=	1.153
Vol. of oil.	÷	Vol. of equal wt. of water	=	Sp. V.

186. A certain weight of a certain acid measures 80 c.c. The same weight of water measures 4 f℥. What is the sp. v. of the acid?

Calculating Specific Volume from Specific Gravity.

Rule.—Divide the sp. gr. into 1.000. The quotient is the sp. v.

$$\text{Sp. V.} = \frac{1.000}{\text{Sp. Gr.}}$$

187. Glycerin has a sp. gr. of 1.25. What is its sp. v.?

1.000 ÷ 1.25 = .800
1.000 ÷ sp. gr. = sp. v.

188. Sulphuric Acid has a sp. gr. of 1.835. What is its sp. v.?
189. Ether has a sp. gr. of .725. What is its sp. v.?

Calculating the Specific Gravity from the Specific Volume.

Rule.—Divide the sp. v. into 1.000. The quotient is the sp. gr.

$$\text{Sp. Gr.} = \frac{1.000}{\text{Sp. v.}}$$

190. Chloroform has a sp. v. of .671. What is the sp. gr.?

1.000 ÷ .671 = 1.490.
1.000 ÷ sp. v. = sp. gr.

B. Reducing Volume to Weight.

1. Cubic Centimeters to Grammes.

The weight of 1 c.c. of water is 1 Gm. The specific gravity of water is 1.000, it being the standard of density. One c.c. of any liquid having a specific gravity of 1.000, will, therefore, weigh 1 Gm. One c.c. of a liquid having a sp. gr. of 2.000, will weigh 2 Gm.; and one c.c. of a liquid having a sp. gr. of .75,

will weigh .75 Gm. In short, *the specific gravity of a liquid indicates the weight in Grammes of one cubic centimeter of it.** Then any volume expressed in cubic centimeters may be converted into weight expressed in Grammes by multiplying the number of cubic centimeters by the specific gravity.— No. of c. c. $\times$ sp. gr. = No. of Gm.

Problems.

191. What is the weight in Gm. of 500 c. c. of glycerin, having a sp. gr. of 1.25?

$$\begin{array}{ccccc} 500 & \times & 1.25 & = & 625. \\ \text{No. of c.c.} & \times & \text{sp. gr.} & = & \text{No. of Gm.} \end{array}$$

192. 2 L. of sulphuric acid, sp. gr., 1.835, weigh how many Gm.?

193. What is the weight in Gm. of 650 c.c. of alcohol, sp. gr., .82?

194. Ether has a sp. gr. of .725. How many Gm. will 5.67 c.c. weigh?

195. Calculate the weight in Gm. of 25 L. of syrup, sp. gr., 1.317.

2. Fluid Ounces to Grains.

The weight of one fl. ounce of water, at 15° C., is 455.7+ gr. Water being the standard of density, it follows that any liquid having a sp. gr. of 1.000, will weigh 455.7 gr. per fl. ounce; that a liquid with a sp. gr. of 2.000, will weigh twice 455.7 gr. per fl. ounce; and that a liquid with a sp. gr. of .900, will weigh $\frac{9}{10}$ of 455.7 gr. per fl. ounce. In every case 455.7 multiplied by the sp. gr. of the liquid will give the

*A c.c. of water weighs 1 Gm. at 4° C., and in vacuo. and the sp. gr. is taken at 15° C., and in air. In case great accuracy is required, correction must therefore be made for temperature, and for pressure. But such corrections are never necessary in pharmaceutical calculations.

weight in grains of one fl. ounce. Then any volume in fl. ounces may be reduced to grains by the following rule:

455.7 gr. $\times$ sp. gr. $\times$ no. of f℥ = wt. in gr.

196. Calculate the weight in gr. of 2 pints 3 fl. ounces of nitric acid, sp. gr., 1.414.

Solution.—455.7 gr. $\times$ 1.414 = 544.3598 gr. (wt. in gr. of 1 fl. ounce).

2 pints 3 fl. ounces = 35 fl. ounces.

Then, 544.36 gr. $\times$ 35 = 19052.6 gr. (wt. of 2 pints 3 fl. ounces.)

Usually the weight in gr. is subsequently to be reduced to weight in higher units.

Note.—In these problems the decimals beyond the second place may be dropped. But this should be done with the least error:—1.158 for instance, should be given as 1.16, not as 1.15.

197. (a.) Find weight in gr. of 14 f℥ of mercury, sp. gr., 13.55. (b.) Express in higher units, avoirdupois.

198. (a.) Calculate weight in av. lb. of 36 gallons of alcohol, sp. gr., .82. (b.) Calculate weight in av. lb. of 1 pint of syrup, sp. gr. 1.317.

199. Calculate weight. in av. lb. of 1 pint of water.

200. Calculate weight in av. lb. of 1 pint of benzine, sp. gr., .67.

201. Calculate weight in av. lb. of 1 pint of sulphuric acid, sp. gr., 1.835.

[Is it a fact that "a pint is a pound"?]

202. Calculate weight, in units of the apoth. system, of 1 O. 3 f℥ 2 fʒ 40 ♏ of alcohol, sp. gr., .82.

203. Calculate weight in Gm. of 1 gallon of ammonia water, sp. gr., .96.

204. Calculate weight in av. lb. of 8 L. of stronger ammonia water, sp. gr., .901.

3. Minims to Grains.

Since 1 fl. ounce equals 480 minims, and since 1 fl. ounce of water weighs 455.7 grains, each minim of water weighs $\frac{455.7}{480}$ grains.

But $\frac{455.7}{480}$ is too cumbersome a fraction for speedy work; a decimal fraction would be more convenient.

$$\frac{455.7}{480} = .9493$$

And this fraction may, for most practical purposes, be rounded off to .95.

Then, if .95 gr. is taken as the weight of 1 ♏ of water, the weight of 1 ♏ of any liquid must be .95 gr. × sp. gr.; and the rule for reducing ♏ to gr. must be —

.95 gr. × sp. gr. × no. of ♏ = weight in gr.

Problems.

205. Find weight in grains of 160 ♏ of solution of ferric chloride, sp. gr., 1.387.

Solution.—

95 gr.	×	1.387	=	1.31765 gr.
Wt. of 1 ♏ of water	×	sp. gr.	=	wt. of 1 ♏ of solution.

Then, 1.31765 gr. × 160 = 210.824 gr. (ans.)

206. Find weight in gr. of 75 ♏ of sulphuric acid, sp. gr. 1.835.

207. Find weight in gr. of 200 ♏ of alcohol, sp. gr., .82.

208. Find weight in gr. of 120 ♏ of chloroform, sp. gr., 1.49.

4. Other Units Apoth. Measure to Apoth. Weight.

One of the chief advantages of the apothecaries' systems lies in this, that the three units of volume most commonly used in prescription work and the three most commonly used weight units are parallels. Thus, the smallest unit of volume, the minim, has its parallel in the grain (which, as has been seen, is, however, not commensurate); and just as 60 minims make 1 fl. drachm, so 60 grains make 1 drachm; and as 8 fl. drachms make 1 fl. ounce, so 8 drachms make 1 ounce. It follows, then, that if 1 minim of water weighs .95 grains, 1 fl. drachm of water must weigh .95 drachms (ʒ), and 1 fl. ounce, .95 ounces (℥). Hence the following rule to reduce fl. drachms of a liquid to weight in drachms:

.95 ʒ* × sp. gr. × No. of fʒ = weight in ʒ.

And the following rule to reduce fl. ounces to ounces:

.95 ℥* × sp. gr. × No. of f℥ = weight in ℥.

Problems.

209. What would be the weight in ℥ of 1 O. 6 f℥ of stronger ammonia water, having a sp. gr. of .91?

210. What would be the weight in ʒ of 3½ fʒ of lactic acid, having a sp. gr. of 1.213?

211. What would be the weight in ʒ of 7¾ fʒ of phosphoric acid, sp. gr., 1.71?

212. What would be the weight in ℥ of 2 O. of diluted alcohol, sp. gr., .938?

Reducing Weight to Volume.

1. Grammes to Cubic Centimeters.

As was explained on page 60 the specific gravity expresses the weight in Grammes of one cubic centimeter. Thus, glycerine, sp. gr., 1.25, means that each cubic centimeter of

*Exactly, .9493 gr., as explained on page 62.

glycerin~~e~~ weighs 1.25 Gm. Then will not 1.25 Gm. of glycerin~~e~~ measure 1 cubic centimeter? Will not 2.5 Gm. of glycerin~~e~~ measure 2 cubic centimeters? Will not 50 Gm. of glycerin~~e~~ measure as many cubic centimeters as 1.25 Gm., the weight of 1 cubic centimeter, is contained in 50 Gm.?

Hence the rule—

Wt. in Gm. ÷ sp. gr. = vol. in c.c.

213. Solution of ferric sulphate has a sp. gr. of 1.32. How many c.c. will 358.5 Gm. measure?

214. A formula calls for 256 Gm of nitric acid, sp. gr., 1.414. But on account of the corrosive action of the acid on the balances, it is much more convenient to *measure* the acid than to weigh it. How many c.c. should be used?

215. A formula calls for 870 Gm. of sulphuric acid, sp. gr., 1.835. How many c.c. should be used?

216. In making ferric chloride, 300 Gm. of hydrochloric acid is to be used. The acid having a sp. gr. of 1.163, how many c.c. should be measured out?

217. [In Germany it is customary to compound all medicines, liquids as well as solids, by weight. It is also customary to state the dose in weight units.]

A certain solution having a sp. gr. of 1.4, is directed to be given in 2 Gm. doses. What would be the dose in c.c.?

218. A certain tincture is directed to be given in 3 Gm. doses. It has a sp. gr. of .86. What should be the dose in ♏?

219. In a certain formula 1 ℥ of nitric acid, sp. gr., 1.414, is required. How many c.c. should be used?

Suggestion.—Reduce 1 ℥ to Gm.; then to c.c.

220. A certain formula calls for 1 kg. of phosphoric acid, sp. gr., 1.71. How many c.c. should be used?

221. A formula calls for 5 oz. of nitric acid, sp. gr., 1.414. How many c.c. should be used.

2. Grains to Fluid Ounces.

As has been shown on page 60, the weight of 1 fl. ounce of any liquid may be calculated if the specific gravity is known, this being used as a multiplier for 455.7 gr., the weight of 1 fl. ounce of water.

Then, if the weight of 1 fl. ounce of the liquid is known, any given weight can be reduced to fl. ounces by dividing the given weight by the weight of 1 fl. ounce.

This may be expressed as follows:

Wt. of liquid in gr. ÷ (455.7 gr. × sp. gr.) = vol. in f℥.

[And, since multiplying the divisor is the same as dividing the dividend, the no. of f℥ may be found also by dividing the weight of the liquid in gr. first by 455.7 gr., then by the sp. gr. — Wt. of liquid in gr. ÷ 455.7 gr. ÷ sp. gr. = vol. in f℥.]

Problems.

222. Calculate the volume in f℥ of 1 lb. of ether, sp. gr., .725.

Solution.—

1 lb. = 7000 gr.

455.7 gr. × .725 = 330.38 gr.

Wt. 1 f℥ of water × sp. gr. = wt. of 1 f℥ of ether.

Then, 7000 gr. ÷ 330.38 (gr.) = 21.198

wt. given ÷ wt. of 1 f℥ = no. of f℥.

223. Find volume in f℥ of 1 lb. of water.

224. Find volume in f℥ of 1 lb. of chloroform, sp. gr., 1.49.

225. Find volume in f℥ of 1 lb. of mercury, sp. gr., 13.558.

226. Find volume in f℥ of 1 lb. of oil of lemon, sp. gr., .858.

227. Find volume in f ℥ of 5℥ 3ʒ 1℈ 10 gr. of solution of ferric chloride, sp. gr., 1.387.

228. Find volume in pints of 5 lb. of nitric acid, sp. gr., 1.414.

229. Find volume in c.c. of 5 lb. of hydrochloric acid, sp. gr., 1.163.

230. Find volume in L. of 50 lb. of glycerin, sp. gr., 1.25.

231. Find volume in pints of 25 Kg. of glycerine, sp. gr., 1.25.

232. One pound (av.) of ether, sp. gr., .725, would fill how many 2 f℥ bottles?

233. One hundred pounds of mercury, sp. gr., 13.558, would fill how many pint bottles?

234. How many fl. ounces in 2 Kg. of chloroform, sp. gr., 1.49?

235. A carboy of stronger ammonia water, sp. gr., .901, contains 115 lb. of the water. How many pints does it contain? How many Liters?

236. A carboy of sulphuric acid, sp. gr., 1.835, contains 142 Kg. How many cubic centimeters does it contain? How many fl. ounces? How many Liters? How many gallons?

237. A druggist buys glycerine, sp. gr., 1.25, at 45c. per lb. and sells a pints at 80c. What is his profit on each pint?

238. A druggist buys chloroform, sp. gr., 1.49 at, 70c. per lb., and sells a Liter for $2.00. Does he gain or lose? How much?

3. Grains to Minims.

Since 1 ♏ of water weighs .95 gr., .95 gr. multiplied by the sp. gr. gives the weight in gr. of 1 ♏ of any liquid and—

No. of gr. given ÷ (.95 gr. × sp. gr.) = vol. in ♏.*

239. Find volume in minims of 200 gr. of chloroform, sp. gr., 1.49.

Solution.— .95 gr. × 1.49 = 1.4155 gr.
Wt. of 1 ♏ of water × sp. gr. = wt. of 1 ♏ of chloroform

Then— 200 gr. ÷ 1.4155 gr. = 141. + (ans.)
No. of gr. given ÷ wt. of 1 ♏ = No. of ♏.

240. Find volume in minims of 90 gr. of lactic acid, sp. gr., 1.213.

4. Drachms and Ounces to Fluid Drachms and Fluid Ounces.

As was explained on page 63, 1 fʒ of water weighs about .95 ʒ; and 1 f℥ of water, about .95 ℥.

Then—, No. of ʒ given ÷ (.95 ʒ × sp. gr.) = vol. in fʒ; and No. of ℥ given ÷ (.95 ℥ × sp. gr.) = vol. in f℥.

The answers will be slightly high, but sufficiently accurate for practical purposes.

241. Find volume in fʒ of 6 ʒ of bromine, sp. gr., 2.99.

242. Find volume in f℥ of 8 ℥ of phosphoric acid, sp. gr., 1.71.

243. Find volume in c.c. of 8 ℥ of phosphoric acid, sp. gr., 1.71.

244. Find volume in f℥ of 250 Gm. of phosphoric acid, sp. gr., 1.71.

---

*Or, No. of gr. given ÷ .95 gr. ÷ sp. gr. = vol. in ♏.

CHAPTER IV.

REDUCING AND ENLARGING FORMULAS.

Let us suppose that just 25 Gm. of compound morphine powder is wanted. The pharmacopœial formula is as follows :

Morphine Sulphate	1 Gm.
Camphor	19 Gm.
Glycyrrhiza	20 Gm.
Precip. Calcium Carbonate	20 Gm.
To make	60 Gm.

Now 25 Gm. is $\frac{25}{60}$ of 60 Gm. So we must multiply the quantity for each ingredient by $\frac{25}{60}$, in order that the mixture may weigh 25 Gm. in place of 60 Gm. That is, we must divide by 60, which would give us the amount to be used for 1 Gm. of powder, and then multiply by 25, because we wish to make 25 times 1 Gm., namely, 25 Gm*.

From the above we may deduce the following general rule: To reduce or enlarge a formula, multiply the quantity of each ingredient by a fraction of which the quantity [of the preparation] to be made is the numerator, and the quantity the formula makes is the denominator. In practice this fraction is always reduced to the simplest expression; $\frac{30}{60}$ becomes $\frac{1}{2}$; $\frac{25}{60}$ becomes $\frac{5}{12}$; $\frac{600}{1000}$ becomes $\frac{6}{10}$ or .6.

Problems.

245. How much vinegar of squill, and how much sugar are required to make 600 c.c. of syrup of squill?

---

* In practice cumbersome fractions are to be avoided when possible. The practical druggist would make 30 Gm. in place of 25; and since $\frac{30}{60} = \frac{1}{2}$, would avoid the lengthy calculation, and save enough time to compensate for the extra 5 Gm. of powder, should the latter be wasted.

U. S. P. formula:		Formula for 600 c.c.
Vinegar Squill	450 c.c.	$\times .6 = 270$ c.c.
Sugar	800 Gm.	$\times .6 = 480$ Gm.
Water q. s.	1000 c.c.	$\times .6 = 600$ c.c.

The formula is for 1000 c.c., but we wish to make 600 c.c. Hence each quantity must be multiplied by $\frac{600}{1000} = .6$.

246. The official formula for tincture of iodine is :—

Iodine, 70 Gm.; alchohol q. s. 1000 c.c. Calculate a formula for 1 pint of the tincture.

Solution.—1 O. = 16 f ℥; and 1 f ℥ = 29.57 c.c.

1 O. = (16 × 29.57) = 473 c.c.

Then 70 Gm. × $\frac{473}{1000}$ [or .473] = 33.11 Gm., the amount of iodine for 1 pint.

247. Calculate the quantities for 1 gallon of soap liniment from the official formula which is as follows :—Soap, 70 Gm.; camphor, 45 Gm.; oil rosemary, 10 c.c.; alcohol, 750 c.c., water, q. s. 1000 c.c.

248. Calculate the formula for 1 Kg. of tooth powder from the following formula :—Powdered soap, 4 oz.; precip. chalk, ½ lb.; camphor, 30 gr.; vanillin, 5 gr.; oil rose, 8 ♏; powdered sugar, 2 oz.; magnesium carbonate, q. s. 1 lb.

Solution.—1 Kg. = 2.2 lb. Hence each quantity is to be multiplied by $\frac{2.2}{1}$, that is, by 2.2.

4 oz. × 2.2 = 8.8 oz.
½ lb. × 2.2 = 1.1 lb.
30 gr. × 2.2 = 66 gr.
5 gr. × 2.2 = 11 gr.
8 ♏ × 2.2 = 17.6 ♏.
2 oz. × 2.2 = 4.4 oz.
Mag. carb. q. s. 2.2 lb. = q. s. 1 Kg.

Note.—Remember that the product is always in the same unit as the multiplicand.

249. The National Formulary gives the following formula for Dewee's Carminative :—magnesium carbonate, 50 Gm. ; tr. asafœtida, 75 c.c. ; tr. opium, 10 c.c. ; sugar, 100 Gm. ; water, q. s. 1000 c.c.

(a.) Calculate quantities for 120 c.c. ; (b.) for 4 f ℥ ; (c.) for ½ Cong. ; (d.) for 2 L. ; (e.) for 3750 c.c.

250. The official formula for compound syrup of squill is :—fl. ext. squill, 80 c.c. ; fl. ext. senega, 80 c.c. ; antimony and potassium tartrate, 2 Gm. ; precip. calcium phosphate, 10 Gm. ; sugar, 750 Gm. ; water, q. s. 1000 c.c.

(a.) Calculate quantities for 1 O. ; (b.) 180 c.c. ; (c.) for 1 Cong.; (d.) for 5850 c.c.; (e.) for 2 O. 6 f ℥.

251. The official formula for belladonna plaster is:—alc. ext. belladonna leaves, 200 Gm. ; resin plaster, 400 Gm. ; soap plaster, 400 Gm.

(a.) Calculate the quantities for 2 lb. ; (b.) for 5 oz. ; (c.) for 5 ℥ ; (d.) for 350 gr. ; (e.) for 5 Kg.

252. A good formula for a permanent blue show globe color is:—copper sulphate, 480 gr. ; sulphuric acid, ½ fluid ounce; water, q. s., 10 fluid ounces.

A certain show globe holds 5 Liters. Calculate a formula for that amount.

253. A formula for deep blue show globe color is:—copper sulphate, 15.5 Gm.; water, 250 c.c. Make solution, to which add—ammonia water, 75 c.c.; and then enough water to make 2 L.

The show globe hold 2 gallons. Calculate a formula for that amount.

254. Hager's Pharm. Praxis gives the following formula for Friedrichshall mineral water:—sodium sulphate, 329.16 Gm.; sodium carbonate, 33.3 Gm.; sodium chloride, 335.39

Gm.; magnesium sulphate, 294.49 Gm.; potassium sulphate, 9.91 Gm.; magnesium chloride, 199.88 Gm.; calcium chloride, 55.75 Gm.; sodium bromide, 6.38 Gm.; water, q. s. 50 L.

Calculate the quantities for a 10 gallon fountain.

Calculating Definite Weight from Parts by Weight.

"Parts-by-weight-formulas" are given in the U. S. Pharmacopœia of 1880, in the latest edition of the German Pharmacopœia (1900), and in many scientific publications. The advantage of such a formula lies in the fact that a part may mean a pound, an ounce (av.), an ounce (apoth.), a grain, a Gramme, a Kilogramme,—in short, any convenient unit of weight. But for formulas for liquids, "parts by weight" were never popular in the United States, because of the established custom in our country of *measuring* liquids.

Problems.

255. Calculate a formula for 5 lb. of salicylated talcum from the following formula of the German Pharmacopœia of 1900:—salicylic acid, 3 parts; wheat starch, 10 parts; talcum, 87 parts.

Solution.—A part in this case is assumed to be a pound. Then the general rule to multiply each quantity by

$$\frac{\text{amount wanted}}{\text{amount formula makes}}$$

is applied. The amount wanted is 5 lb.; the formula makes 100. Hence each quantity is multiplied by $\frac{5}{100}$ or .05.

Thus we have—

Salicylic acid	3 lb. × .05 = .15 lb.
Wheat starch	10 lb. × .05 = .5 lb.
Talcum	87 lb. × .05 = 4.35 lb.

The fractions of pounds should, of course, be reduced to lower units.

256. Suppose 500 Gm. of the salicylated talcum are wanted. Each part is assumed to be a Gramme. Then—

$$3 \text{ Gm.} \times \frac{50\cancel{0}}{1\cancel{0}\cancel{0}} = 15 \text{ Gm.}$$

$$10 \text{ Gm.} \times 5 = 50 \text{ Gm.}$$

$$87 \text{ Gm.} \times 5 = 435 \text{ Gm.}$$

257. Suppose 480 gr. are wanted for a prescription. Each part = 1 gr. Then—

$$3 \text{ gr.} \times \tfrac{480}{100} = 14.4 \text{ gr.}$$

$$10 \text{ gr.} \times 4.8 = 48. \text{ gr.}$$

$$87 \text{ gr.} \times 4.8 = 417.6 \text{ gr.}$$

258. The German Pharmacopœia of 1900 gives the following formula for powder of magnesia and rhubarb:—magnesium carbonate, 50 parts; eleosaccharate of fennel oil, 35 parts; rhubarb, 15 parts. (a.) Calculate quantities for 600 Gm. of the powder; (b.) for 2 Kg.; (c.) for 2 lb.; (d.) for 8 ℥; (e.) for 8 oz; (f.) for 300 gr.; (g.) for 6 ℥ 2 ʒ 1 ℈ 10 gr.

259. Recipé for polishing paste:—oxalic acid, 1 part; jewelers' rouge, 16 parts; rotten stone, 20 parts; palm oil, 59 parts; petrolatum, 4 parts. (a.) Calculate formula for 1 lb.; (b.) for 1 Kg.; (c.) for 12 oz.; (d.) for 400 Gm.

CHAPTER V.

Proportions.

To solve the problem—If 20 lb. of tartaric acid cost $7.00, how much will 32 lb. cost?—we reason as follows:—1 lb. of acid will cost $7.00 ÷ 20 = $.35; and 32 lb. will cost 32 times as much as 1 lb., hence $.35 × 32 = $11.20.

We may arrive at the same answer by an operation based upon a different line of reasoning, thus:—Price and quantity in this problem bear such a relationship to each other that they increase and decrease in the same ratio. If, for instance, the quantity is doubled, is raised to 40 lb., the price must be doubled likewise, must be raised to $14.00*. If the quantity is reduced to one-fourth, to 5 lb., the price becomes $7.00 ÷ 4 = $1.75. Then if we can find the ratio of 20 lb. to 32 lb., we have also the ratio of $7.00 to the answer sought.

When this definite relationship exists between values—when they increase and decrease in the same ratio—the values are said to be proportional to each other. Thus, quantities and prices are proportional.

The statement that 20 lb. bears the same relation to 32 lb. as $7.00 bears to $11.20, is called a statement of a proportion. The statement may be more concise as follows.—

20 lb. is to 32 lb., as $7.00 is to $11.20.

For *is to*, it is customary to use the sign of ratio, the colon [:]; and for *as*, the sign of proportion, the double colon [: :]. Thus—

20 lb.	:	32 lb.	: :	$7.00	:	$11.20
	is to		as		is to	

*Notice that the increase is not dollar per pound, *but at the same rate* in case of the dollars as in case of the pounds.

Each one of the members of the proportion is called a term. Terms are numbered from left to right. Thus in the preceding example 20 lb. is the *first* term, 32 lb., the *second* term, $7.00, the *third* term, and $11.20, the *fourth.*

The first two terms constitute the *first couplet*, and the last two, the *second couplet.*

The first and last terms are called the *extremes;* the second and the third, being in the middle, are called the *means.*

$$\overbrace{\underset{\text{1st term}}{20\text{ lb.}} \quad : \quad \underset{\text{2nd term}}{32\text{ lb.}}}^{\text{1st couplet}} \quad :: \quad \overbrace{\underset{\text{3d term}}{\$7.00} \quad : \quad \underset{\text{4th term}}{\$11.20}}^{\text{2nd couplet}}$$

means

extremes

It will be seen that the product obtained by multiplying the two means, and the product obtained by multiplying the two extremes are the same.

$$20 \times 11.20 = 224.00$$
$$32 \times 7.00 = 224.00$$

It follows that the product of the extremes divided by either mean will give the other mean. And the product of the means divided by either extreme will give the other extreme.

$$224 \div 20 = 11.20; \; 224 \div 11.20 = 20$$
$$224 \div 32 = 7.00; \; 224 \div 7.00 = 32$$

Hence if three terms are known, the fourth one may be calculated.

The missing term may be any one of the four.

1. If 20 lb. of acid cost $7.00, how many lb. of acid may be bought for $11.20?

2. If 32 lb. cost $11.20, how many lb. could be bought for $7.00?

3. If 20 lb. cost $7.00, how much would 32 lb. cost?

4. If 32 lb. cost $11.20. how much would 20 lb. cost?

Stating the proportion.—

In stating a proportion it is, however, easier to avoid error if the proportion be always so stated that the missing term is the fourth term.

The following rules will be found serviceable:

1. Let the 3d term be that number which expresses the same kind of value as will be expressed by the answer sought.

2. Then decide whether the answer sought is to be greater or smaller than this 3d term. If greater, place the greater of the two remaining terms as the 2nd term; if smaller, place the smaller of the two remaining terms as the second.

3. The remaining known term place as the first.

Note.—The 1st and 2nd terms must be in the same unit of value, in order that the ratio of the abstract numbers may also be the ratio of the denominate numbers.

Since the missing term is one of the extremes, it is obtained by multiplying the two means—the 2nd term and the 3d—and dividing the product by the 1st term*.

Note.—The answer will be in the same unit as the 3d term. If it is to be in a different unit it must subsequently be reduced to that unit.

PROBLEM.—If 437.5 gr. (1 oz.) of phenacetine cost 95c, how much will 120 gr. (2 ʒ) cost?

Solution.—The three known terms are—95c, 437.5 gr., 120 gr.

The answer will express cost, i. e., money-value. There-

*This is identical with dividing the known term of the second couplet by the ratio of the 1st term to the 2nd.

fore the known term expressing cost should be the third term:

: : : 95c : x (answer).

Since the quantity for which the cost is to be found is less than the quantity for which the price is given, the answer will be smaller than the third term. Hence the smaller of the two remaining terms is to be the second :

: 120 gr. : : 95c : x

As but one known term remains unplaced, this must be the first :

437.5 gr. : 120 gr. : : 95c : x

The 1st and 2d terms may now be treated as abstract numbers :

$95c \times 120 = 11400c$
$11400c \div 437.5 = 26c.$ (answer.)*

Solving the problem by analysis, we would reason thus :—if 437.5 gr. cost 95c, 1 gr. will cost 95c ÷ 437.; and 120 gr. will cost 120 times as much as 1 gr. In this case the division is carried out first, and the quotient is multiplied, while in the proportion the multiplication is cerried out first and the division last. One of the fundamental rules of arithmetic is that multiplication and division may be carried out in any order. So a proportion could be completed by dividing the first term into the second or third, and then multiplying the remaining known term by the quotient. But it is preferable to carry division out last—not only in proportions, but in all

*Cancellation.

The figuring may frequently be lessened by cancellation. That is, by dividing the first term by a certain number, and then one of the other terms by the same number, which process in no way changes the values.

Example.— $\overset{3}{\cancel{27}\cancel{0}} : \overset{91}{\cancel{81}\cancel{9}} :: 35\cancel{0} : x$

The first term and also the third may be divided by 10 by cancelling the ciphers. Then the first term and the second may each be divided by 9. The work has now been simplified to $91 \times 35 \div 3$.

problems;—for the reason that the quotient may be burdened with an interminate decimal, the rounding off of which occasions an error, an error that a subsequent multiplication would magnify.

Problems.

260. If cocaine costs $6.50 an oz., how much will 3 ʒ cost?

Solution.—The three known terms are: $6.50, 1 oz., and 3 ʒ. The answer is to express cost. Hence—

: : : $6.50 : x

The 1st and 2d terms must be in the same unit. In this problem the 1 oz. and the 3 ʒ are best reduced to gr.

1 oz. = 4.375 gr., and 3 ʒ = 180 gr. [If the cost were known per ℥, it would be simpler to reduce to ʒ.]

The quantity for which the cost is to be found is *smaller* than the quantity for which cost is given. Hence the answer will be *smaller*—

437.5 gr. : 180 gr. : : $6.50 : x

$6.50 × 180 = $1,170.00; $1,170.00 ÷ 437.5 = $2.67.

261. (a.) If cocaine costs $6.50 an oz., how much will 2 ʒ 1 ℈ 5 gr. cost? (b.) How much will 2 Gm. cost? (c.) How much will 3.256 Gm. cost?

262. (a.) If chloral hydrate costs $1.30 a lb., how much will 1 ℥ cost? (b.) How much will 10.560 Gm. cost?

263. (a.) If cream of tartar costs 60c. per Kg. (Kilo.), how much will 1 lb. cost? (b.) How much will 1 ℥ cost? (c.) How much will $2\frac{3}{4}$ oz. cost? (d.) How much will 2 ℥ 2 ʒ 2 ℈ 2 gr. cost?

264. If homatropine costs $6.00 a Gm., how many gr. can be bought for $1.75?

Remarks.—The answer is to express quantity; hence 1 Gm.

is the 3d term. The answer will be in Gm., and must be reduced to gr.

265. If homatropine costs \$6.00 a Gm., how much would 2 gr. cost?

266. If 15 gr. of heroin cost 18c, how much is 1 oz. worth?

267. (a.) If alcohol costs \$2.40 a gallon, how much does a Liter cost? (b.) How much do 225 c.c. cost? (c.) How much do 2 O. 6 f℥ cost?

268. How many Cong. of alcohol, quoted at \$2.40 a gal., can be bought for \$100.00?

269. Glycerin cost 23c per lb. Its sp. gr. is 1.25. How much does it cost a Liter?

Solution.—1 L. = 1000 c.c.;
1000 × 1.25 (sp. gr.) = 1250 Gm.
1 lb. = 453.6 Gm.

Then 453.6 Gm. : 1250 Gm. :: 23c : x $67\frac{8}{10}$c.

NOTE.—Quantity is proportional to price; and the quantity may be expressed in weight or volume, and in any unit of these, provided the 1st and 2d terms are in the same unit. So this and similar problems may be solved in several different ways.

270. Oil of lemon costs \$1.25 a lb., and has a sp. gr. of .858. How much does it cost per f℥?

271. (a.) Mercury costs \$1.50 per Kg. Taking its sp. gr. as 13.5, how much would 4 f℥ cost? (b.) How much would 12 c.c. cost? (c.) How much would 2 fʒ 45 ♏ cost?

272. Alcohol costs \$2.40 a gal., and has a sp. gr. of .82. How much does it cost per lb.?

273. Castor oil costs 14c. a lb., and has a sp. gr. of .95. How much does it cost a gal.?

274. Chloroform costs 60c. a lb., and has a sp. gr. of 1.49. How many f℥ can be bought for 75c?

275. How many pints of chloroform could be bought for $10.00?

276. What would be the cost of 4 f℥ of chloroform?

277. (a.) If 8 f℥ of ether, sp. gr. .725, cost 50c., how much does it cost per lb.? (b.) How much per Kg.?

CHAPTER VI.

PERCENTAGE PROBLEMS.

Percentage—abbreviated percent., and indicated by the symbol %—means parts per 100 parts.

Opium, said to contain 14% of morphine, contains 14 parts of the latter to 86 parts of other constituents, making 100 parts in all.

The amount of a constituent in a drug, the amount of component in a mixture or in a preparation, the amount of dissolved substance in a solution,—all these amounts are conveniently expressed in percentages; that is, they are conveniently adjusted to the scale of 100*.

This being true, problems involving percentages are of frequent occurrence in every-day work.

In such problems the following factors come into play:

1. The amount of drug, mixture, preparation, or solution, or whatever is to represent the 100 parts.

2. The amount of constituent or ingredient.

3. The amount of constituent or ingredient as expressed in percentage.

4. The amount of drug, mixture, etc., expressed in percentage. This is always 100, and is never sought as an answer.

5. The amount of diluent or solvent.

For sake of brevity let us designate drug, mixture, preparation, or solution by M, standing for mixture; constituent or ingredient by C, standing for constituent; percentage by its customary symbol, %; and diluent or solvent by D.

---

*In order that comparisons may be readily made—made by inspection—such data should be reduced to *some* common standard or scale; and the number 100 is selected, rather than 12, 144, or any other number, for arithmetical reasons.

In percentage problems there are four cases possible: (1) M may be sought, the other factors being known; (2) C may be sought; (3) % may be the element to be calculated; (4) the amount of diluent or solvent may be sought.

It should be remembered that percentages in pharmaceutical or chemical problems refer to parts *by weight*, unless the contrary is expressly stated. Now, if percentages stand for parts by weight, they are proportional to weights of M and of C, and any one of the first three factors—M, C, or %—may be calculated by proportion.

D is the difference between C and M, and is found by subtracting C from M. See page 87.

Examples.

1. Suppose that 6 Gm. of opium on analysis are found to contain .585 Gm. of morphine, and the morphine-strength of the opium is to be expressed in percentage.

The three known terms are:—6 Gm. (amount of M), .585 Gm. (amount of C), 100% (% of M)*.

The missing term is % of C.

Since the answer is to be in percent., the known percent. 100% (M is always assumed to be 100%), must be the third term.

$$: \quad :: 100\% : x$$

The answer is to be smaller than 100%, because the amount of C (.585 Gm.) is smaller than the amount of M (6 Gm.) Or, to generalize, the percent. of C must always be less than 100, because a part is less than the whole. Therefore the

*Remember that M always stands for the medicinal substance or preparation in its totality. So in this and the immediately succeeding problems it stands for opium, and not for morphine, although the latter word begins with *m*. The choice of drug and constituent might *appear* unfortunate; but the selection of a constituent with a name beginning with *m* was premeditated, the object being to point out that the symbols M and C are general, and have no relationship to the names of specific drugs, or of preparations, or of constituents.

smaller of the two remaining known terms is the second, and the larger, the first.

6 Gm. : .585 Gm. : : 100% : x
x = 9.75%.

2. How much morphine is present in 60 Gm. of opium having a morphine strength of 12%?

The three known terms are:—60 Gm. (amount of M), 12% (% of C), and 100% (% of M).

The answer is to express weight. Therefore —

: : : 60 Gm. : x

The answer is to be smaller than 60 Gm., because 12% is less than 100%. And because C, the part, must weigh less than M, the whole.

Then the smaller remaining term (12%) must be the second. Thus—

100% : 12% : : 60 Gm. : x
x = 7.2 Gm.

3. If a certain opium has a morphine-strength of 14%, how much of the opium would contain just 5 Gm. of morphine?

The known terms are:—100% (% of M), 14% (% of C), and 5 Gm. (wt. of C).

The term sought is wt. of M.

Since the answer is to be in weight, the known weight is the third term.

: : : 5 Gm. : x

The answer is to be greater, because 100% is greater than 14%, and because the whole must be greater than the part. Hence—

14% : 100% : : 5 Gm. : x
x = 35.714 Gm.

While the rules on page 75 for stating proportions are always applicable, and cannot mislead, it is well to know that in percentage proportions correctly stated, M and C alternate; that is, the term giving % of M and the one giving weight of M are never side by side, but have another term between them,—which is true likewise, for the two terms giving respectively weight and % of C.

Observe the three proportions just given.

1.	6 Gm. wt. of M.	:	.585 Gm. wt. of C	: :	100% % of M	: (x)	9.75% % of C
2.	100% % of M	:	12% % of C	: :	60 Gm. wt. of M.	: (x)	7.2 Gm. wt. of C
3.	14% % of C	:	100% % of M	: :	5 Gm. wt. of C	: (x)	35.714 Gm. wt. of M

N. B.—A similar alternation occurs in all proportions in which the two values are *directly* proportional; if they are inversely proportional [see page 101] the alternation does not occur.

OTHER ARITHMETICAL PROCESSES.

Problem 1 may be solved also by reasoning as follows: If 6 Gm. of opium contains .585 Gm. of morphine, 1 Gm. of opium will contain .585 Gm. ÷ 6 = .0975 Gm.; and 100 Gm. will contain 100 times as much as 1 Gm., hence [.0975 Gm. × 100 =] 9.75 Gm.

Consequently the answer is, 9.75%.

Formulating this we have—

$$\% = (C \div M) \times 100 \text{ or, } \% = \frac{C \times 100}{M}$$

Problem 2 is solved as follows: If the morphine strength of the opium is 12%, each 100 Gm. of the latter contains 12 Gm. of morphine, and 1 Gm. of opium contains 12 Gm. ÷ 100 = .12 Gm. Then 60 Gm. contains 60 times as much as 1 Gm., that is [.12 Gm. × 60 =], 7.2 Gm.

Expressing the above process in a formula, we have—

$$C = (\% \div 100) \times M. \text{ or, } C = \frac{\% \times M}{100}$$

Problem 3: If the morphine-strength of the opium is 14%, 100 Gm. of the latter contain 14 Gm. of morphine. Then 1 Gm. of morphine will be contained in [100 Gm. ÷ 14 Gm. =] 7.1428 Gm. of opium; and 5 Gm. of morphine will be contained in 7.1428 Gm. × 5 = 35.714 Gm.

This expressed in a formula gives:

$$M = (100 \div \%) \times C. \text{ or, } M = \frac{100 \times C}{\%}$$

The same result may be obtained as follows: In 100 Gm. of opium there are 14 Gm. of morphine. In 1 Gm. of opium there are 14 Gm. ÷ 100 = .14 Gm. of morphine. Then the answer will be — as many Gm. of opium as .14 Gm. is contained in 5 Gm. = 35.714 Gm.

Formula—

$$M = C \div \% \div 100.$$

Since dividing the divisor is the same as multiplying the dividend,

$\frac{100 \times C}{\%} = C \div \% \div 100$, and the two processes must give the same answer;—must both be correct.

Advice to Students.

Some students have a tendency to follow blindly memorized arithmetical formulas or rules—such as the preceding, for instance. Such formulas are soon forgotten, or are remembered but imperfectly, and become a stumbling block rather than a help. Those who cannot solve percentage problems by a process of reasoning, are strongly advised to avoid the preceding formulas, and to solve the problems by proportion. The principles underlying proportions are soon mastered by the average students; and by the exceptional ones, who are absolutely unmathematical, the process may

be followed empirically without danger of error, as, in proportions, no matter what the case—no matter which factor is missing—the rules to be followed are the same.

Problems.

278. A certain drug contains 17% of soluble matter, hence will yield 17% of extract. How much extract could be obtained from 500 Gm. of the drug?

279. How many lbs. of the same drug would be required to make 5 lbs. of extract?

280. What is the percent. of extractable matter in a certain licorice root, 500 Gm. of which yield 90 Gm. of extract?

281. Diluted hydrocyanic acid, U. S. P., contains 2% of absolute hydrocyanic acid (HCN), the remainder being water. How much absolute HCN in 450 Gm.?

282. Official nitric acid contains 68% of absolute nitric acid (HNO_3), the remaining 32% being water. How many gr. of absolute HNO_3 in 400 gr.?

283. How many Gm. of iodine in 300 Gm. of a 5% solution?

284. How much iodine should be weighed out to make 1 Kg. of a 5% solution?

285. How many Gm. of 5% soda solution can be made from 400 Gm. of soda?

286. What is the percentage strength of a solution of homatropine made by dissolving 15 gr. in enough water to make 400 gr.?

287. Stronger ammonia water, U. S. P., contains 28% of ammonia gas (NH_3). How many Gm. of the stronger ammonia water would contain 40 Gm. of the gas?

288. What is the percentage strength of a solution of mercuric chloride made by dissolving 60 gr. of the latter in enough water to make 5,000 gr.?

289. What is the percentage strength of a solution of sodium chloride made by dissolving 65 gr. of the salt in 400 gr. of water?

Solution.— 65 gr. in 400 gr. would make 465 gr. of solution. The three known terms are: [400 + 65 =] 465 gr., 65 gr., 100%. Percentage is asked for. Hence—

: : : 100% : x.

The answer is to be less than 100%. Hence—

465 gr. : 65 gr. : : 100% : (x) 13.9%.

290. What is the percentage strength of a solution of carbolic acid in glycerin made by mixing 350 Gm. of the latter with 200 Gm. of the acid?

291. Boric acid is soluble in 25.6 parts of water*. What is the percentage strength of a saturated solution?

292. Potassium chlorate is soluble in 16.7 parts of water. What is the percent. strength of a saturated solution?

293. One part of water will dissolve 1.33⅓ parts of potassium iodide. What is the percent. strength of a saturated solution?

294. One part of water will dissolve $\frac{1}{16}$ part of potassium permanganate. What is the percent. strength of a saturated solution?

295. What percentage of sugar in a syrup made from 1 lb. of sugar and ½ lb. of water?

*The parts referred to are parts by weight; hence are proportional to percentages. The known terms are: [1 part (acid) + 25.6 parts (water) =] 26.6 parts (solution), 1 part (acid), 100% (% strength of solution).

CALCULATING AMOUNT OF DILUENT OR SOLVENT.

[To make 100 Gm. of a 15% solution of salt we may proceed in two ways: we may weigh out 15 Gm. of salt, and then add enough water to bring the total weight to 100 Gm.; or, we may add to the 15 Gm. of salt 85 Gm. of water, previously weighed. In the first method there is a possibility of adding too much water; and as solution begins at once, the excess of water cannot be removed without removing some salt also. For this reason the second method is preferred.]

296. How many lbs. of sugar, and how many of water, are required to make 12 lbs. of syrup having a sugar-content of 65%?

Solution.— 100% : 65% :: 12 lbs. : x
x = 7.8 lbs. (wt. of sugar).

Then— 12 lbs. — 7.8 lbs. = 4.2 lbs. (wt. of water).

297. In how many Gm. of water must 15 Gm. of cocaine hydrochlorid be dissolved to make a 4% solution?

Solution.— 4% : 100% : 15 Gm. : x
x = 375 Gm. (wt. of solution to be made).

Then 375 Gm. (wt. of solution) — 15 Gm. (wt. of cocaine) = 360 Gm. (wt. of water).

298. How many Gm. of magnesium sulphate, and how many Gm. of water, are required to make 600 Gm. of 28% solution?

299. How many oz. of carbolic acid, and how many of petrolatum, must be used to make 32 oz. of carbolated petrolatum containing 3% of carbolic acid?

300. How many Gm. of water must be used to dissolve 4 Gm. of mercuric chloride to make a $\frac{1}{10}$% solution?

301. A certain nasal spray consists of liquid petrolatum,

with 6% of menthol, 5% of eucalyptol, and 2% of thymol. How much must be used of each of the ingredients to make 150 Gm?

Solution.—100% : 6% : : 150 Gm. : x
x = 9 Gm. (am't of menthol).
100% : 5% : : 150 Gm : x
x = 7.5 Gm. (am't of eucalyptol).
100% : 2% : : 150 Gm. : x
x = 3 Gm. (am't of thymol).

Then— 9 Gm. + 7.5 Gm. + 3 Gm. = 19.5 Gm. (am't of active ingredients);

And— 150 Gm. (am't of spray) — 19.5 Gm. (am't of active ingredients) = 130.5 Gm. (am't of liquid petrolatum).

302. ℞ Iodoform gr. xxx
Boric acid ʒ j
Naphthalin ʒ j

Make a fine powder, and flavor with 2% of oil of bergamot. How much of the latter must be used?

Percentage Problems Involving Conversion from One System of Weight to Another.

303. How many Gm. of 4% solution can be made with 1 oz. of cocaine hydrochloride?

304. What is the percent. strength of a morphine sulphate solution made by dissolving ⅛ oz. in enough water to make 100 Gm.?

305. To make 5 lbs. of 5% solution of soda, how many Gm. of the latter must be used?

306. How many Gm. of 2% atropine sulphate solution can be made with 1 ʒ 1 ℈ 10 gr.?

307. To make 75 Gm. of 4% solution of cocaine hydrochloride, how many gr. of the latter must be used, and how many Gm. of water?

308. How many ℥ of sodium thiosulphate must be used to make 2 lbs. (av.) of 15% solution?

Problems Involving Also Reduction of Volumes to Weights, or Weights to Volumes.

Since in these problems—and always when the contrary is not expressly stated—percentages stand for parts by weight, they are proportional to weights, *but not to volumes.* If quantities [of M or of C] are given in volumes, these must be reduced to weights before employing the quantities as terms in proportions. If the answers (4th terms) of these proportions represent quantities, these will be in weight—not in volume. So a conversion to volume must follow whenever the answer is to express volume.

309. Official nitric acid has a sp. gr. of 1.414, and contains 68% of absolute acid. How many Gm. of abs. acid in 2 L. of the official acid?

Solution.—2 L. = 2000 c.c.

2000 × 1.414 = 2828. Hence 2000 c.c. = 2828 Gm.

Then 100% : 68% : : 2828 Gm. : x

x = 1923.04 Gm. (wt. of abs. acid).

310. Official solution of potassa has a sp. gr. of 1.036, and contains 5% of potassa. How many f℥ of solution could be made from 20 Gm. of potassa?

Solution.—5% : 100% : : 20 Gm. : x

x = 400 Gm. (weight of solution).

400 ÷ 1.036 = 386.1. Hence, 400 Gm. = 386.1 c.c. (volume in c.c.).

386.1 ÷ 29.57 = 13.057. Hence, 386.1 c.c. = 13.057 f℥, or 13 f℥ 27 ♏.

311. Official syrup contains 85 Gm. of sugar in 100 c.c., and has a sp. gr. of 1.317. What percent. of sugar does it contain?

Solution.—The sp. gr. being 1.317, 100 c.c. of syrup weigh 131.7 Gm.

Then— 131.7 Gm. : 85 Gm. : : 100% : x

x = 64.54%.

312. Stronger ammonia water has a sp. gr. of .901, and contains 28% of ammonia. How many Gm. of the latter in 1 pint of the stronger water?

313. Official sulphuric acid has a sp. gr. of 1.835, and contains 92.5% of absolute acid. (a.) How many gr. of absolute acid in 1 fʒ of official acid? (b.) How many Gm. of abs. acid in 2 L. of official acid?

314. Official solution of ferric citrate has a sp. gr. of 1.25; and 1 L. yields 531.25 Gm. of ferric citrate (scale salt). What percent. of ferric citrate in the solution?

315. How many gallons of ammonia water, having a sp. gr. of .96, and containing 10% of ammonia gas, could be made from 1 Kg. of the latter?

316. In a certain chemical reaction 5 Gm. of absolute hydrochloric acid (HCl) is required. To supply it how many c.c. of official acid—sp. gr., 1.163, absolute-acid-content, 31.9% —must be used?

317. If 2 L. of absolute alcohol, sp. gr., .79, is diluted with water so as to make 91% alcohol, sp. gr., .82, how much of the latter alcohol will result?

318. 30 c.c. of ether, sp. gr., .725, is dissolved in enough alcohol to make 100 c.c. of solution, the latter having a sp. gr. of .8. What percent. of ether (by weight) in the preparation?

319. Lead subacetate solution has a sp. gr. of 1.195, and

contains 25% of lead subacetate. On diluting 3 c.c. of this solution to 100 c.c., diluted solution of lead subacetate (U. S. P.) is obtained. How much lead subacetate does the latter solution contain in each f℥?

Solution.—1 f℥ = 29.57 c.c. If 100 c.c. of the diluted solution contain 3 c.c. of the strong solution, 1 c.c. of the diluted solution will contain 3 c.c. ÷ 100 = .03 c.c. of the strong; and 29.57 c.c. of the diluted solution will contain .03 c.c. × 29.57 = .8871 c.c. of the strong solution. The sp. gr. of the latter being 1.195, the .8871 c.c. weighs [.8871 × 1.195 =] 1.061 Gm. Of this 25% is lead subacetate. Then—

100% : 25% :: 1.061 Gm. : (x) .265 Gm.

320. Solution of ferric sulphate has a sp. gr. of 1.32, and contains 28.7% of ferric sulphate. How many gr. of ferric sulphate in 1 f℥ of a diluted solution, containing 20 c.c. of the official solution in 100 c.c.?

To Calculate Amount of Constituent.

A. In Case a Definite Volume of Solution is Required, and its Sp. Gr. is Unknown.

Suggestion.—In making a solution of definite percentage strength, the weight of that volume of solvent which is identical with the volume of solution required, may be taken as the basis of calculation, and the amount of constituent found as follows:

% of solvent [% M — % C] : % of constituent :: wt. of solvent : x

x = wt. of constituent.

Since the solvent itself measures as much as the solution required, and since the volume of the former is increased by the dissolved constituent, the finished product will exceed the

required volume somewhat. The latter may be measured out, and the excess either preserved or rejected,—according to its amount, stability, commercial value, etc.

Example.—Suppose, for instance, that 1 f℥ of 4% solution of cocaine hydrochloride is required. Since the sp. gr. is not given, it is impossible to convert 1 f℥ of the solution to weight; and hence it is impossible to calculate the quantity of cocaine for 1 f℥.

Now, a f℥ of water weighs 455.7 gr., and the quantity of cocaine required to convert this much water into 4% solution of cocaine *can* be calculated:—The solution is to be 4%; then the water in it must represent 96%; and—

96%	:	4%	: :	455.7 gr.	:	(x) 18.98 gr.
% of water		% of cocaine		wt. of water		wt. of cocaine

Thus by dissolving 18.98 gr. of cocaine in 1 f℥ of water, a solution results containing exactly 4% of the cocaine. But its volume is a trifle over 1 f℥*; so the latter volume may be measured out, and the remainder, which is about 14 drops, either rejected, or preserved for future use.

The practical pharmacist soon learns to guess at the quantity of solution to be made by weight in order to furnish a volume slightly in excess of a certain required volume; but the guess must be based upon the reasoning employed in the preceding example.

321. How would you proceed to fill the following prescriptions; calling respecting for—

(a.) 1 L. of 2% solution of mercuric chloride.

(b.) 100 c.c. of 20% solution of morphine acetate.

---

*The exact volume of increase due to the solution of the 19 gr. of cocaine is supposed to be unknown beforehand. If it were known, it would be equivalent to knowing the sp. gr.

It is well to remember that the volume of a solution of a solid is greater than the volume of the solvent alone, but is less than the combined volumes of solid and solvent.

(c.) 2 f℥ of 4% solution of homatropine.

322. (d.) 2 f℥ of 5% solution of iodine, in alcohol, sp. gr. .82.

(e.) 1 f℥ of 20% solution of tannic acid, in glycerin, sp. gr. 1.25.

B. Sp. Gr. of Solution Unknown, but Slight Deficiency in Volume Permissible.

In the following procedure it is assumed that the dissolved substance will augment the volume practically as much as would an equal weight of the solvent. In reality it never does; and the higher the percentage of dissolved substance in solutions made by the following method, the greater is the discrepancy between the volume desired and the volume actually obtained.

Method illustrated by example.—Suppose, for instance, that 100 c.c of 5% solution of salt is wanted. In place of using 100 c.c. of water, and enough salt to make a 5% solution, as directed in the preceding article, 100 Gm. of solution is made, using 95 Gm. (c.c.) of water, and 5 Gm. of salt. Since the 5 Gm. of dissolved salt will not augment the volume to the extent of 5 c.c., the volume of the solution will fall short of 100 c.c.

Or suppose that 1 f℥ of 4% solution of cocaine hydrochloride is wanted.

100% : 4% : : 455.7 gr. : (x) 18.2 gr.

Hence 18.2 gr. of cocaine, and 437.5 gr. of water are used, making 455.7 gr. of solution, which is precisely 4% strong, but the volume of which falls short of being 1 f℥*.

*If in place of adding enough water to make 455.7 gr., enough is added to make 1 fluid ounce, the solution will weigh more than 455.7 gr.; and consequently its percentage strength will be too low—will be below 4%.

Many physicians would consider the difference to be too trifling to deserve notice. However, in the absence of special permission, the conscientious pharmacist will take no "short cuts" which in the least affect the strength of a medicinal preparation.

This procedure may be stated as follows:

Make as much solution by weight as that volume of solvent weighs which is equal to the volume of solution required, and calculate amount of constituent [C] in the usual manner.

323. How much solution by weight should be made, and how much constituent, used in the following prescriptions.—

(a.) 20 c.c. of 5% solution of apomorphine hydrochloride.

(b.) 1 f℥ of 8% solution of iodoform in ether, sp. gr. of the latter being .725.

324. How many Gm. of cocaine hydrochloride is required to make 60 c.c. of 6% solution?

325. How many Gm. of camphor is required to make 1 L. of an 8% solution in cotton seed oil, the latter having a sp. gr. of .92?

326. How many gr. of each constituent must be used to make 2 f℥ of eye lotion containing $\frac{1}{4}$% of zinc sulphate, $\frac{1}{8}$% of morphine sulphate, and 2% of boric acid?

[NOTE.—In these problems a shortage in volume of product is assumed to be permissible.]

VOLUME PERCENTAGE.

A volume percentage solution is one having in 100 volumes a definite number of volumes of constituent, the latter necessarily being a liquid. Thus, alcohol, U. S., contains 94% by volume of absolute ethyl hydroxide, the remaining 6% by volume being water. Diluted alcohol, U. S., contains 48.6% by volume of ethyl hydroxide, and 51.4% by volume of water.

Notice that it is expressly stated that the percentage is by volume. When such a statement is absent, weight percentage is always understood.

Since percentages in volume percentage stand for volumes, they are proportional to volumes. It follows that the succeeding problems may be calculated by proportions.

Problems.

327. In 1 Cong. of alcohol, containing 94% by vol. of ethyl hydroxide, there are how many f℥ of the latter?

328. In 5 L. of diluted alcohol, containing 48.6% by vol. of ethyl hydroxide, there are how many c.c. of the latter?

329. A certain alcohol contains 6 O. 8 f℥ of abs. ethyl hydroxide in each Cong. What % by vol. of ethyl hydroxide does the alcohol contain?

330. A certain menstruum is to contain 15% by volume of glycerine. How much of the latter should a pint contain?

Calculating Volume Percentage to Weight Percentage and Vice Versa.

If the sp. gr. of the constituent is known, and also the sp. gr. of the solution, volume percentage may be calculated to weight percentage,—and vice versa.

Rect. Spt B. P 40

Example.—Alcohol, U. S., containing 94% by volume of ethyl hydroxide contains what % by weight?

Spt

Solution.—The sp. gr. of the alcohol [solution] is given as .82; that of ethyl hydroxide [constituent] as .79. If the sp. gr. of the alcohol is .82, 100 c.c. of it weigh 82 Gm. If the sp. gr. of the ethyl hydroxide is .79, 94 c.c. of it would weigh [94 × .79=] 74.26 Gm. 71.46

Then— 85.6 + % vol

82 Gm.	:	74.26 Gm.	: :	100%	:	(x) 90.56%
wt. of M	:	wt. of C	: :	% by wt. of M	:	% by wt. of C

RS = 85.65

Example.—Alcohol is 91% strong by weight. Calculate strength in volume percentage.

R.S .834 = 119.79 cm³

Solution.— 100 Gm. of alcohol = 100 ÷ .82 = 121.9 c.c.
91 Gm. of ethyl hydroxide = 91 ÷ .79 = 115 c.c.

85.65 " " " = 85.65 ÷ 0.794 = 107.8

119.79 107.87 90 % 10 P

Then 121.9 c.c.	:	115 c.c.	: :	100%	:	(x) 94 + %
vol. of M	:	vol. of C	: :	vol. % of M	:	vol. % of C

331. The sp. gr. of ethyl hydroxide being .79, what is the wt. percent. strength of an alcohol of 66% by vol., and having a sp. gr. of .9?

332. An alcohol has a sp. gr. of .8721, and contains 70% by wt. of ethyl hydroxide [sp. gr. .79]. What % by vol. of the latter does it contain.

[See Squibb's alcohol table, U. S. P., page 531 et seq.]

NOTE.—By the Internal Revenue Office strength of alcoholic liquids is expressed by degrees proof. An alcoholic liquid containing 50% by vol. of absolute ethyl hydroxide is said to be 100 proof. Common alcohol, 94% by vol. strong, is said therefore to be 188 proof. In short—degrees proof ÷ 2 = strength in % by vol.; and % by vol. × 2 = degrees proof.

Problem.—What is the alcohol strength of brandy marked 110 proof?

Solution.—110 ÷ 2 = 55% by vol.

WEIGHT TO VOLUME SOLUTIONS.

As has been pointed out, the exact amount of a solid constituent in a given volume of a percentage solution can be calculated only when the sp. gr. is known, and is made a factor in the calculation. Now, for percentage solutions prepared on physicians' prescriptions the sp. gr. is generally unknown; consequently the amount of constituent in a f℥, or in a ♏, or in any dose measured by volume, cannot be determined with accuracy. This being true, physicians frequently find percentage solutions ill adapted to their wants, and prefer solutions containing *a definite weight in a definite volume.* [See U. S. P. for strength of tinctures, and other liquid preparations.] The strength of weight to volume solutions may be expressed in gr. to the fʒ, gr. to the f℥, gr. to the pint (O.), Gm. to 100 c.c., Gm. to the L., gr. too 100 ♏, etc.

By some physicians the strength of solutions is expressed as illustrated in the following—"1 in 100," "5 in 100," etc., in which cases the pharmacist can only surmise, but cannot know, whether the second number stands for parts by weight or for parts by volume.

Much confusion has been caused also by the misapplication of the term percentage in expressing the strength of weight to volume solutions. The strength of such solutions cannot be expressed in percentage. A solution containing 4 gr. of atropine sulphate in 100 ♏ is not exactly a 4% solution, for a ♏ of the solvent—water—weighs a little less than .95 gr.,* and, secondly, the sp. gr. of a solution is not the same as that of the solvent.

How, then, should the term percentage be interpreted? In view of the fact that a 4 gr. to 100 ♏ solution is more convenient than a percentage solution when the medicine is intended for internal or for hypodermic use, and in view of the fact that in prescriptions the term percentage may have a special meaning—how should a prescription calling for 1 f℥ of 4% atropine sulphate solution be filled? The argument that a 4 gr. to 100 ♏ solution is better adapted to the physicians' wants is a good one; but it is an argument for the use of weight to volume solutions in preference to percentage solutions, and not an argument for the misapplication of the term percentage. The fact that the latter term is often misapplied—that physicians may order percentage solutions, and expect weight to volume solutions—points to the desirability of a special interpretation from the author of the prescription†.

*In case of metric prescriptions, weight to volume solutions differ from percentage solution only to the extent that the sp. gr. of the solution differs from that of water; for 100 c.c. of water weigh 100 Gm.

†It has been the writer's observation that pharmacists who admit that they are not clear on the subject of percentage solutions, understand the subject perfectly. What they do not understand is, when to dispense weight to volume solutions on prescriptions calling for percentage solutions. This is not a question of arithmetic; nor is it a question which can be argued:—it is a question which can be answered by no one except the author of the prescription.

But in the absence of such an interpretation, it is proper to apply to the term percentage its conventional and generally accepted meaning, and to dispense a 4 gr. to 100 gr. solution.

The physician, on being communicated with in regard to the subject, may answer that in his opinion the difference is too slight to deserve cognizance in practical medicine;—an answer which to the pharmacist is fully as satisfactory as a direct answer to his question. It should be remembered, however, that such an opinion is not held by all physicians, and that the pharmacist should be reasonably exact in his work, no matter how much guess-work may, at times, be necessary in practical medicine.

Much of the aforementioned confusion would disappear if there were brought into general use a symbol corresponding to the percentage symbol, %, but applicable to weight to volume solutions. In the problems which follow the symbol W/V is used, and signifies units by weight in 100 commensurate, or nearly commensurate volume units. Thus, for example, 1 fʒ of 4W/V solution would call for 1 fʒ of a solution containing 4 gr. of constituent in 100 ♏; and 30 c.c. of 4W/V solution, for 30 c.c. of a solution containing 4 Gm. of constituent in 100 c.c.

In W/V solutions, c.c. of solution are proportional to Gm. of constituent; and ♏ of solution to gr. of constituent.

Problem.—How many gr. of homatropine are required to make 1 f℥ of a 4W/V solution?

Solution.—Since 4W/V means 4 gr. to 100 ♏, the volume of the solution must be expressed in ♏.—1 f℥ = 480 ♏.

Then— 100 ♏	:	480 ♏	: :	4 gr.	:	(x) 19.2 gr.
				am't in 100 ♏		am't in 480 ♏

[Or: If 100 ♏ of solution contains 4 gr. of constituent, 4 gr. ÷ 100 = .04 gr. is the amount of constituent in each ♏; and .04 gr. × 480 = 19.2 gr., the amount in 480 ♏.]

Problems.

333. How many gr. of cocaine hydrochloride are required to make 4 fʒ of a 6 $^{W}/_{V}$ solution?

334. How many f℥ of a 4 $^{W}/_{V}$ solution could be made from 1 oz. of cocaine hydrochloride?

335. What would be the $^{W}/_{V}$ strength of a solution of boric acid made by dissolving 1 oz. of the latter in enough water to make 2 pints of solution?

Other Methods for Expression of Strength of Solutions.

To avoid fractions, the strength of very dilute solutions is sometimes expressed in parts in 1000, in 2000, 5000, or even in 10000.

The solution of mercuric chloride, used as an antiseptic by surgeons, offers a case in point. The parts referred to may be parts by weight, or (in case of liquid constituents) parts by volume; and in addition, there may be the weight to volume solutions mentioned on page 96. But the sp. gr. of these very dilute solutions is so nearly 1.000, that 1 c.c. may be considered as equivalent to 1 Gm. in all cases, and 1 f℥ as equivalent to 455.7 gr.

336. How many gr. of mercuric chloride are required to make 1 lb. of a 1 in 1000 solution?

337. How many Gm. are required to make 2 L. of a 1 in 3000 solution?

338. How many gr. are required to make 1 pint of a 1 in 1000 solution?

NOTE.—The error due to the assumption that 1 pint of solution weighs as much as a pint of water, is so minute that the difference in the weight of constituent required would be an unweighable difference.

339. How many gr. of mercuric chloride are required to

make 2 f℥ of a solution, 1 fʒ of which diluted to ½ pint would make a 1 gr. to 2000 ♏ solution?

Solution.—Since ½ pint = 64 fʒ, the solution should be 64 times as strong as a 1 gr. in 2000 ♏ solution, that is, it should be a 64 gr. in 2000 ♏ solution.

Then— 2000 ♏ : 960 ♏ : : 64 gr. : (x) 30.72 gr.

340. How many Gm. of mercuric chloride should be weighed out to make 120 c.c. of a solution 25 c.c. of which diluted to a L. would make a 1 Gm. in 3000 c.c. solution?

CHAPTER VII.

CONCENTRATION AND DILUTION.

If 100 Gm. of a 10% salt solution is diluted to 200 Gm., that is, to double its original weight, the percentage of salt will thereby be reduced to 5%, that is, to one-half the original percentage. If the solution is diluted to four times its original weight, the percentage strength falls to one-fourth of the original percentage strength. If on the other hand the 10% salt solution is concentrated from 100 Gm. to 50 Gm. [the solvent being evaporated off without effecting loss of salt], the percentage strength is thereby doubled—becomes 20%. Thus it is seen that with the *amount* of constituent remaining unchanged, the percentage strength decreases in the same ratio in which the quantity of solution is increased, and increases in the same ratio in which the quantity of solution is decreased.

As quantity of solution and percentage strength change in the same ratio, these two values are proportional to each other; but as the change is in opposite directions, they are said to be *inversely* proportional. However, the general rules for stating proportions, as given on page 75, are applicable to inverse proportions as well as to direct proportions.

With the amount of constituent (C) remaining constant, the following factors come into consideration in concentration and dilution problems:

1. Initial amount of solution (or mixture, or preparation).
2. Amount after dilution or concentration.
3. Initial percentage strength of solution (or mixture, or preparation).
4. Percentage strength after dilution or concentration.

If any three of these factors are given, the fourth may be found by proportion.

If amount of diluent (to be added) is required, this is found by subtracting the initial amount of solution (or mixture, or preparation) from the amount after dilution.

N. B.—Since percentage is commonly weight percentage, the amounts must be in weight except when the percentage is expressly stated to be volume percentage, in which cases the amounts must be in volume.

Problems.

341. What is the % strength of a salt solution obtained by diluting 10 lb. of a 10% solution to 14 lb.?

Solution.—Percentage is asked for. Hence—

: : : 10% : x

After dilution the strength will be less than 10%. Hence the smaller of the remaining terms is the second, and the larger the first:

14 lb. : 10 lb. : : 10% : (x) $7\frac{1}{7}$%

342. What is the % strength of a salt solution obtained by evaporating 10 lb. of a 10% solution to 8 lb.?

Solution.—Percentage is asked for. Hence—

: : : 10% : x

After concentration the strength will be over 10%. Hence—

8 lb. : 10 lb. : : 10% : (x) $12\frac{1}{2}$%.

343. To what weight must 500 Gm. of 10% salt solution be evaporated in order to make a 16% solution?

Solution.—Weight is asked for; and after concentration the solution will weigh less than 500 Gm. Hence—

16% : 10% : : 500 Gm. : (x) 312.5 Gm.

344. How many Gm. of 10% nitric acid (the diluted nitric acid of the U. S. P.) can be made from 300 Gm. of nitric acid containing 68% of abs. acid?

345. How many lb. of acetic acid, 32% strength, are required to make 10 lb. of diluted acetic acid, which contains 6% of abs. acid?

346. What is the % strength of ammonia water obtained by diluting 500 Gm. of stronger ammonia water, containing 28% of ammonia, to 1800 Gm.?

347. In order to bring a certain extract of opium to the official morphine strength (18%) 1 lb. 4 oz. had to be evaporated to 14 oz. What was the morphine strength of the extract prior to the evaporation?

348. To what weight must 1 kg. of alcohol, 91%, be diluted to make alcohol of 41% strength?

349. How many Gm. of sulphuric acid, 70%, can be made from 4 lb. of acid of 92.5% strength?

N. B.—**The two terms of a couplet must be in the same unit.**

350. How many lb. of hydrochloric acid, 31.9%, are required to make 5 kg. of 10% hydrochloric acid?

351. How many gallons of alcohol, 94% by vol., are required to make 25 L. of alcohol of the strength of 50% by vol.?

352. To what weight must 600 c.c. of solution of sodium hydroxide—sp. gr., 1.437; strength, 40%—be diluted in order to make a 5% solution?

N. B.—**Amount must be in weight for proportion.**

353. What is the % strength of a diluted hydrochloric acid obtained by diluting 1 L. of hydrochloric acid—sp. gr., 1.163; strength, 31.9%—to 5 lb.?

354. Diluted hydrocyanic acid should contain 2% of abs. acid. To how many Gm. must 1 lb. 5 oz. 200 gr. of a 2.35% acid be diluted in order to reduce it to official strength—to 2%?

355. To how many f℥ must 500 c.c. of alcohol—sp. gr. .82; strength 91%—be diluted in order to make 58% alcohol having a sp. gr. of .9?

Suggestion.—Convert 500 c.c. to Gm.; find weight of dilution by proportion. Answer is in Gm. Convert to c.c.; then to f℥.

356. A certain lump of opium on assaying is found to contain 9% of morphine, and 22% of moisture. What will be the morphine strength of the opium after drying [to make powdered opium]?

Solution.—If the opium contains 22% of moisture, 100 parts will make 78 parts of the dried opium. Since no morphine is lost in the drying, the % strength will be higher, i. e., the answer will be greater than 9%. Hence—

78 parts : 100 parts :: 9% : (x) 11.53%.

357. [The official extract of nux vomica is a powdered extract, and is standardized to contain 15% of alkaloids. On evaporating the natural extract to dryness, it usually yields a product containing more than 15% of alkaloids. The diluent used is milk sugar; and to insure its thorough incorporation, it is to be added while the extract is still of the consistency of a syrup. To calculate at this point the amount of milk sugar required, it is necessary to know the alkaloidal strength of the syrupy extract, and also the percentage of moisture present.]

Problem.—The syrupy extract of nux vomica is found to contain 14% of alkaloids, and 20% of moisture. How much milk sugar must be added to 600 Gm. of the extract in order

to yield a product which after drying will contain 15% of alkaloids?

Solution.—(1) If the moisture amounts to 20%, the yield of dry extract is 80% of 600 Gm.

100%	:	80%	: :	600	:	(x) 480 Gm.
% of syr. ext.		% of dry ext.		wt. of syr. ext.		wt. of dry ext.

(2.) The alkaloidal strength of the dry extract is greater than 14%. Hence—

480 Gm. : 600 Gm. : : 14% : (x) 17.5%

(3.) If the strength of this dry extract is to be lowered from 17.5% to 15%, the extract must be diluted to—

15% : 17.5% : : 480 Gm. : (x) 560 Gm.

(4.) To dilute the extract from 480 Gm. to 560 Gm., [560 Gm. — 480 Gm. =] 80 Gm. of milk sugar must be added.

The four steps of the process are:

(1.) Finding the amount of dry extract the syrupy extract will yield.

(2.) Finding the % strength of the dry extract.

(3.) Finding the weight to which the dry extract would require dilution to reduce the strength to 15%.

(4.) Finding by difference the amount of diluent to be added.

358. A certain lot of syrupy extract of nux vomica contains 12% of alkaloids and 46% of moisture. How much milk sugar must be added to 5 lb. 6 oz. to yield a product containing 15% of alkaloids after drying?

359. A certain lump of opium contains 28% of moisture, and 8% of morphine. (a.) How much morphine could be obtained from 500 Gm. of dried opium prepared from this

lump? (b.) How much milk sugar would be required to reduce 200 Gm. of the dried opium to a morphine strength of 10%?

360. Tincture of ferric chloride has a sp. gr. of .96, and contains 13.6% of anhydrous ferric chloride. The solution of ferric chloride has a sp. gr. of 1.387, and contains 37.8% of anhydrous ferric chloride. How many c.c. of the solution are required to make 100 c.c. of the tincture?

Solution.—100 c.c. of tincture weigh 96 Gm.

Then— 37.8% : 13.6% :: 96 Gm. : x (Gm. of sol. required)

x = 34.54 Gm.

And 34.54 ÷ 1.387 (sp. gr.) = 24.9 +. Hence 34.54 Gm. = 24.9 c.c.

361. To make 100 c.c. of paregoric of the official strength .4 Gm. of opium containing not less than 13% [nor more than 15%] of morphine, must be used. If the opium contains only 9% of morphine, how much should be used for each 100 c.c. of paregoric?

Pharmacopœial Rules for Dilution of Alcohol.

Designate the weight-percentage of the stronger alcohol by W, and the desired strength by w.

Rule.—Mix w parts by weight of the stronger alcohol with water to make W parts by weight of the product.

Example.—An alcohol of 50% by weight is to be made from an alcohol of 91% by weight.—Take 50 parts by weight of the 91% alcohol, and add enough water to produce 91 parts by weight.

Note.—In case the strength of alcohol is given in volume-percentage, the same rule is used, except that parts by volume are taken in place of parts by weight, and that, after cooling, more water is added to make up for contraction which occurs.

Remarks.

This rule is simply an application of the general rule given on page 101:—if the amount of constituent is constant, the amount

of solution [or mixture] varies inversely as the percentage strength —that is, is inversely proportional to the percentage strength.

If the amount of diluted alcohol required is not the same as is made by following the pharmacopœial rule, a subsequent calculation becomes necessary.

Example.—How much 91% alcohol is required to make 300 Gm. of 50% alcohol ?—Applying the pharmacopœial rule, we find that 50 Gm. of 91% alcohol will make 91 Gm. of 50% alcohol. But 300 Gm.—not 91 Gm.—are wanted. The amount of the 91% alcohol for 300 Gm. must bear the same ratio to 300 Gm. as 50 bears to 91.

That is—91 : 50 : : 300 Gm. : (x) 164.83 Gm.

But this is exactly the same calculation as would be based on our general rule, without reference to the pharmacopœial rule. Thus :—The answer is to be weight ; hence 300 Gm. must constitute the third term. To make 300 Gm. of 50% alcohol would require *less* than 300 Gm. of the stronger alcohol ; hence the smaller of the two remaining terms must be the second, and the larger the first ; giving—91% : 50% : : 300 Gm. : (x) 164.83 Gm.

CHAPTER VIII.

ALLIGATION.*

Alligation Medial.

COMPUTING THE PERCENTAGE STRENGTH OF A MIXTURE, OR SOLUTION, WHEN THE AMOUNTS AND THE PERCENTAGE STRENGTHS OF THE SEVERAL INGREDIENTS ARE GIVEN.

Problem.—A wholesale druggist mixes 5 lb. of opium containing 9% of morphine, 3 lb. of opium containing 6% of morphine, and 10 lb. of opium containing 12%. What is the morphine strength of the mixture?

Solution.— 5 lb. of 9% opium contain as much morphine as [5 × 9 =] 45 lb. of 1% opium would contain.

3 lb. of 6% opium contain as much morphine as [3 × 6 =] 18 lb. of 1% opium.

10 lb. of 12% opium contain as much morphine as [10 × 12 =] 120 lb. of 1% opium.

Then the 18 lb. of product [5 lb. + 3 lb. + 10 lb.] contain as much morphine as 183 lb. [45 lb. + 18 lb. + 120 lb.] of 1% opium would contain. And the morphine strength of the product must be as many times 1% as 18 lb. is contained in 183 lb. 183 ÷ 18 = 10.16. Hence the morphine strength of the product is 10.16%.

This operation my be made the basis of the following rule:

1. Multiply the amounts of the several ingredients (all of which must be expressed in the same unit) by their percentage strengths.

---

*From the Latin *alligare*, to bind:—referring to the linking together of values in alligation alternate, as shown on page 112.

$$5[\text{lb.}] \times 9[\%] = 45.\ [\%\ \text{units}].$$
$$3[\text{lb.}] \times 6[\%] = 18.\ [\%\ \text{units}].$$
$$10[\text{lb.}] \times 12[\%] = 120.\ [\%\ \text{units}].$$

2. Add the products.

$$45 + 18 + 120 = 183\ [\%\ \text{units}].$$

3. Add also the amounts.

$$5 + 3 + 10 = 18[\text{lb.}]$$

4. Divide the sum of the products by the sum of the amounts.

$$183 \div 18 = 10.16.$$

The quotient is the percentage strength of the mixture.

Note.—In case the strengths are given in volume-percentage, the amounts must be in volume; if in weight-percentage, the amounts must be in weight, as in the example.

Problems.

365. A drug house receives two shipments of cinchona. The first, consisting of 500 lb., contains on an average 3.3% of quinine. The second, consisting of 300 lb., contains 2.1% of quinine. What is the quinine strength of the product obtained by mixing the two lots?

366. A druggist finds in his laboratory the following lots of diluted alcohol: 1500 c.c., 60% by vol. strong, 400 c.c., 40% by vol. strong, 1 pint, 50% by vol. strong. What is the strength of the product obtained by mixing the three lots?

Computing the Specific Gravity of a Mixture When the Amounts and the Specific Gravities of the Ingredients are Given.

The principles of alligation medial apply also to specific gravities. But it is required that the amounts be in volume,

and not in weight; for specific gravity expresses the weight of a unit of volume—not of a unit of weight.*

367. What would be the sp. gr. of the product obtained by mixing 3000 c.c. of benzin and 1200 c.c. of naphtha, the former having a sp. gr. of .67, and the latter of .718?

Solution.—

$$\begin{array}{lr} 3000 \text{ c.c.} \times .67 \text{ [sp. gr.]} = & 2010 \text{ Gm.} \\ 1200 \text{ c.c.} \times .718 \text{ [sp. gr.]} = & 861.6 \text{ Gm.} \\ \hline 4200 \text{ c.c.} & 2871.6 \text{ Gm.} \end{array}$$

$$2871.6 \div 4200 = .683 \text{ (sp. gr. of mixture).}$$

369. What would be the sp. gr. of a mixture of 2 f℥ of bromoform, sp. gr., 2.9, and 8 f℥ of chloroform, sp. gr., 1.49?

370. What would be the sp. gr. of a mixture of 150 Gm. of ether, sp. gr., .725, and 200 Gm. of chloroform, sp. gr., 1.49?

Suggestion.—Reduce Gm. to c.c.; then proceed by alligation medial.

371. What would be the sp. gr. of a mixture of 1 pint of alcohol, sp. gr., .82, and 1 lb. of ether, sp. gr., .725?

---

*A cubic centimeter of water weighs 1 Gramme. A c.c. of a liquid having a sp. gr. of 3., weighs 3 Gm. On mixing 1 c.c. of water, sp. gr. 1, with 1 c.c. of the liquid, sp. gr., 3, we get 2 c.c. of product, weighing $1 + 3 = 4$ Gm. If 2 c.c. weigh 4 Gm., 1 c.c. will weigh 4 Gm $\div 2 = 2$ Gm. Then the sp. gr. of the product must be 2, which by laboratory experiment can be proven to be correct.

But suppose that 1 Gm. of water and 1 Gm. of the liquid are mixed. What will be the sp. gr. of the product?

*Mis*applying the rule to weights we obtain the same answer as before—namely, sp. gr., 2. This cannot be correct if the answer to the first problem is correct; for the proportion of 1 Gm. of water to 1 Gm. of the liquid is the same as 1 c.c. of water to $\frac{1}{3}$ c.c. of the liquid, while in the first problem we have 1 c.c. of each. But on reducing the weights to volume, and then applying the rule, we obtain for an answer the sp. gr. of 1.5.

$$\begin{array}{lr} 1 \text{ c.c.} \times 1 \text{ [sp. gr.]} = & 1 \text{Gm.} \\ \frac{1}{3} \text{ c.c.} \times 3 \text{ [sp. gr.]} = & 1 \text{Gm.} \\ \hline 1\frac{1}{3} \text{ c.c.} & 2 \text{Gm.} \end{array} \qquad \text{Then } 2 \div 1\tfrac{1}{3} = 1.5. \text{ [sp. gr. of mixt.]}$$

This by laboratory experiment can be proven to be correct. [In practice it is difficult to find two liquids of which one has a sp. gr. just three times that of the other. Even numbers were used in the example for sake of brevity and simplicity. For the laboratory experiment any two liquids which are miscible, and differ considerably in sp. gr., may be used.]

Alligation Alternate.

To Find the Proportion in Which Ingredients of Known Strength Must be Mixed to make a Mixture of Required Strength.

Problem.—In what proportion must opium 10% strong and opium 14% strong be mixed to make opium 13% strong?

Solution.—The strength of the stronger opium is 1% too high; that of the weaker opium is 3% too low. Since the difference between the strength of the stronger opium and the required strength is just $\frac{1}{3}$ as great as the difference between the strength of the weaker opium and the required strength, three parts of the stronger opium must be taken to one part of the weaker. In other words, the excess in strength of three parts of the stronger opium will just balance the deficiency of one part of the weaker opium.

Problem.—In what proportion must opium 10% strong and opium 15% strong be mixed to make opium 13% strong?

Solution.—The weaker opium is 3% too weak; the stronger is 2% too strong. Then the excess in strength of 3 parts of the stronger will just balance the deficiency of 2 parts of the weaker. For 2 [parts] × 3 [%] = 6; and 3 [parts] × 2 [%] = 6.

[The same principle applies in alligation alternate as is applied in writing chemical formulæ.—The formula for Zinc Phosphid is $Zn_3 P_2$. Now Zinc has 2 valencies, and phosphorus has 3. Hence 3 atoms of bivalent Zinc have as many valencies (6) as 2 atoms of trivalent phosphorus. In like manner 3 parts of the opium which is 2% too strong will fortify to the required strength 2 parts of the opium which is 3% too weak.]

General Rule.

Percent. of *stronger* ingredient minus desired percent. equals parts of *weaker* ingredient.

Percent. desired minus percent. of *weaker* ingredient equals parts of *stronger* ingredient.

In case there are more than two ingredients, their percentage strengths must be paired off so that the difference between each percentage strength and the required percentage strength is just compensated for by the proper number of parts of the opposite kind.

Problem.—In what proportion must alcohol, 20% strong, alcohol, 40% strong, alcohol, 65% strong, and alcohol, 90% strong, be mixed to make alcohol which is 50% strong.

Proceed as follows:

1. Write the percentages in a column [preferably in numerical order]. Place a brace [{] in front of the column, and in front of the brace write the required percentage. Thus—

$$50\% \begin{cases} 20\% \\ 40\% \\ 65\% \\ 90\% \end{cases}$$

2. Connect with a line each percentage which is greater than the required percentage with one that is less than the required percentage; and each one that is less with one that is greater than the required percentage. Thus—

$$50\% \begin{cases} 20\% \\ 40\% \\ 65\% \\ 90\% \end{cases} \quad \text{or} \quad 50\% \begin{cases} 20\% \\ 40\% \\ 65\% \\ 90\% \end{cases}$$

3. Write the difference between the first percentage and the required percentage opposite the percentage connected

with the first percentage by a line. Proceed in this manner with all the percentages, in each case writing the difference not opposite the percentage compared, but opposite the percentage at the other end of the line. Thus—

50%	20 % = 40	The difference between 20% and 50% being 30%, 30 is placed opposite 90%.
	40 % = 15	
	65 % = 10	
	90 % = 30	The difference between 40% and 50% being 10%, 10 is placed opposite the 65%.

The difference between 65% and 50% being 15, 15 is placed opposite the 40%. The difference between 90% and 50% being 40, 40 is placed opposite the 20%.

The differences denote the number of parts which should be used of the several ingredients to make a mixture of the desired strength. In case of weight-percentage the proportionate parts are parts by weight; and in case of volume percentage they are parts by volume.

Proof.

By Alligation Medial.

40 [parts]	× 20 [%] =	800	[% units]
15 [parts]	× 40 [%] =	600	[% units]
10 [parts]	× 65 [%] =	650	[% units]
30 [parts]	× 90 [%] =	2700	[% units]
95 [parts]	contain	4750	[% units]

Then— 4750 ÷ 95 = 50%.

Remarks.—When there are more than three ingredients, a number of correct answers are possible, because the percentages may be paired off in different ways. And even in case of but three ingredients—when but one answer is obtainable by alligation—the ingredients may be mixed in an indefinite number of proportions. So the answer obtained by alliga-

tion, in case of three ingredients, is not the only correct answer: it is *a* correct answer. And the answers obtained by alligation in case of four or more ingredients, are *not all*, but *only some*, of the correct answers.

In Case Either the Weaker or the Stronger Ingredients Exceed in Number.

Problem.—A wholesale druggist has five lots of opium—8%, 10%, 12%, 14% and 15% morphine strength respectively. In what proportion *may* these be mixed in order to make a product of 13% morphine strength?

Proceed as in the preceding example, except that one of the percentages must be connected with *two* others:

$$13\% \begin{cases} 8\% = 2 \\ 10\% = 1 \\ 12\% = 1 \\ 14\% = 1 + 3 = 4 \\ 15\% = 5. \end{cases}$$

As the 14% is connected with *two* other percentages, the difference between 14% and the required percentage must be placed opposite *both* the percentages thus connected; i. e., opposite the 10%, and the 12%. And the difference between 10% and 13%, and the difference between 12% and 13%, are both to be placed opposite the 14%.

Question.—How many correct answers to this problem are obtainable by alligation alternate?

Problems.

376. In what proportion should alcohol, 91% strong, be mixed with alcohol, 48% strong, to make alcohol 70% strong?

377. In what proportion must cinchona containing 11% of total alkaloid, cinchona containing 8%, and cinchona containing 4%, be mixed to make a product containing 5% of alkaloids?

378. In what proportion should jalap containing 15% resin, jalap containing 17%, jalap containing 10%, and jalap containing 8%, be mixed to make a product containing 12%?

In case of fractional parts.

379. In what proportion must coca .8% strong be mixed with coca .38% strong to make a product .5% strong?

Solution.—

$$.50\% \begin{cases} .38\% = .30 \text{ parts, which} \times 100 = 30 \text{ parts.} \\ .80\% = .12 \text{ parts, which} \times 100 = 12 \text{ parts.} \end{cases}$$

Note.—As fractions are cumbersome, eliminate them by multiplication. In this case multiply by 100.

380. In what proportion should belladonna, .38%, belladonna, .18%, and belladonna, .30%, be mixed to make a product .35% strong?

In Case Active Constituents, or Diluents, or Both are Ingredients in the Mixture.

Problem.—In what proportion must chloroform be added to a 20% solution of chloroform to increase the strength of the latter to 35%?

Solution.—The chloroform figures in the calculation as a 100% solution, thus—

$$35\% \begin{cases} 20\% = 65 \text{ parts} \quad 13 \text{ parts} \\ \qquad\qquad\qquad\qquad \text{or} \\ 100\% = 15 \text{ parts} \quad 3 \text{ parts} \end{cases}$$

Then 65 parts of solution require 15 parts of chloroform. Or, reducing the ratio to its simplest expression by cancellation—13 parts of solution require 3 parts of chloroform.

Problem.—In what proportion should alcohol, 91% strong, alcohol, 48% strong, and water be mixed to make a product 35% strong?

Solution.—The water may be considered as an alcohol of zero percentage. Then—

$$35\% \left\{ \begin{array}{l} 0\% \text{ (water)} = 13 + 56 = 69 \text{ parts.} \\ 48\% = 35 \text{ parts.} \\ 91\% = 35 \text{ parts.} \end{array} \right.$$

Problems.

383. In what proportion must potassium iodide be added to a potassium iodide solution 15% strong in order to increase its strength to 25%?

384. In what proportion should opium 10% strong, opium 15% strong, and milk sugar be mixed to make a product 13% strong?

385. In what proportion should absolute acetic acid, acetic acid 36% strong, and water be mixed to make acetic acid 60% strong?

To Find the Proportion in Which Ingredients of Given Specific Gravities Must be Mixed to Make a Mixture of Given Specific Gravity.

Alligation Alternate is Applicable to Volumes of Liquids and their Specific Gravities.*

Problem.—In what proportion by volume must petrolatum, sp. gr., .82, be mixed with petrolatum, sp. gr., .85, to make a product having the sp. gr. of .83?

Solution.—

$$.83 \left\{ \begin{array}{l} .82 = .02 \times 100 = 2. \text{ parts.} \\ .85 = .01 \times 100 = 1. \text{ parts.} \end{array} \right.$$

---

*The parts calculated from specific gravities are in every case parts by volume. See page 110.

In some instances changes in volume take place, due to chemical action. The answers obtained are then only approximately correct. See dilution of alcohol, page 106.

Eliminating the fractions, the answer is, 2 parts by volume of the lighter to 1 part by volume of the heavier petrolatum.

Problems.

387. In what proportion by volume should ether, sp. gr., .725, chloroform, sp. gr., 1.49, and alcohol, sp. gr., .82, be mixed to make a product having the sp. gr. of 1.000?

388. In what proportion by volume should glycerin, sp. gr., 1.25, alcohol, sp. gr., .82, be mixed to make a product having a sp. gr. of .95?

389. In stock we have two solutions of soda, the sp. gr. of one being 1.06, that of the other, 1.5. In what proportion must these be mixed to yield a product of the sp. gr. of 1.225?

In Case the Quantity of One of the Ingredients is Specified, and the Quantity of the Other Ingredients is to be Calculated.

Problem.—How much scammony having a resin-content of 82% must be mixed with 5 lb. of scammony having a resin-content of 93%, to make a product having a resin-content of 90%?

Solution.—By alligation alternate we determine in what proportion the two qualities must be mixed:

$$90\% \begin{cases} 82\% = 3 \text{ parts.} \\ 93\% = 8 \text{ parts.} \end{cases}$$

From the proportionate parts we calculate the quantities by proportion:

The three known terms are — 3 parts, 8 parts, and 5 lb. Since quantity (weight) is asked for, 5 lb. must be the third term. The quantity of the weaker scammony is asked for; and as this is to be used in the proportion of 3 parts to 8 of

the other, 3 being less than 8, the answer is to be smaller than 5 lb. Hence—

$$8 \text{ parts} : 3 \text{ parts} :: 5 \text{ lb.} : (x)\ 1\tfrac{7}{8} \text{ lb.} = 1 \text{ lb. } 14 \text{ oz.}$$

In order that confusion may be avoided it is well to place the given quantity opposite the proportionate parts which are to be taken of the ingredient for which the quantity is given; thus—

$$90 \begin{cases} 82\% = 3 \text{ parts} = ? \\ 93\% = 8 \text{ parts} = 5 \text{ lb.} \end{cases}$$

The known terms may now be located without difficulty; and whether the answer should be greater or smaller than the given quantity—the third term—may be seen by inspection. The interrogation point follows "3 parts" in the example; a given quantity follows "8 parts". Since 3 is smaller than 8, the answer must be smaller than 5 lb.—the given quantity.

Problem.—How much alcohol, 45% strong, how much 60% strong, and how much water, should be mixed with 500 Gm. of alcohol, 90% strong, in order that the product may have a strength of 50%?

Solution.—

$$50\% \left\{ \begin{array}{lll} 0\% \text{ (water)} & = 40 \text{ parts} & = ? \\ 45\% & = 10 \text{ parts} & = ? \\ 60\% & = 5 \text{ parts} & = ? \\ 90\% & = 50 \text{ parts} & = 500 \text{ Gm} \end{array} \right.$$

Then by proportion*:

$$50 \text{ parts} : 40 \text{ parts} :: 500 \text{ Gm.} : x\ (400 \text{ Gm.})$$
$$50 \text{ parts} : 10 \text{ parts} :: 500 \text{ Gm.} : x\ (100 \text{ Gm.})$$
$$50 \text{ parts} : 5 \text{ parts} :: 500 \text{ Gm.} : x\ (50 \text{ Gm.})$$

*The general proportion is—
parts of ingredient, quantity of which is given : parts of ingredient, quantity of which is sought :: quantity given : x
x = quantity sought.

Proof.

400 Gm.	× 0% =	0%	unit
100 Gm.	× 45% =	4500%	units
50 Gm.	× 50% =	3000%	units
and 500 Gm.	× 90% =	45000%	units
1050 Gm.		52500%	units

52500 ÷ 1050 = 50[%].

Problems.

392. How many Gm. of nitric acid, 68% strong, must be added to 500 Gm. of acid, 10% strong, to make a product 50% strong?

393. How many Gm. of sulphuric acid, 90% strong, must be added to 1 L. of water to make an acid 10% strong?

394. How many c.c. of water should be added to 1 L. of a solution of soda, sp. gr., 1.4, in order to make a solution of the sp. gr. of 1.2?

395. How many f℥ of ammonia water, sp. gr., .96, must, be added to 8 f℥ of ammonia water, sp. gr., .92, to make a product having a sp. gr. of .95?

396. How many c.c. of ether, sp. gr., .725, must be added to 1 L. of chloroform, sp. gr., 1.49, to yield a product of the sp. gr. of 1.25?

In Case the Quantity is Specified for Several Ingredients.

Problem.—We have 5 lb. of acetic acid, 28% strong, 3 lb. of acetic acid, 20% strong, and 1 lb., 10% strong. How much glacial acetic acid, 99% strong, should be added to a mixture of these in order that the product may have the strength of 36%?

Solution.—

$$\begin{array}{lll} 5 \text{ lb.} \times 28\% & = & 140\% \text{ units} \\ 3 \text{ “} \times 20 \text{ “} & = & 60 \text{ “ “} \\ 1 \text{ “} = 10 \text{ “} & = & 10 \text{ “ “} \\ \hline 9 \text{ lb.} & & 210\% \text{ units} \end{array}$$

$$210 \div 9 = 23\tfrac{1}{3}\ \%$$

A mixture of the given quantities would be $23\frac{1}{3}\%$ strong, and the weight of the mixtures would be 9 lb. The problem has now been simplified to — How much acetic acid 99% strong must be added to 9 lb. of acid $23\frac{1}{3}\%$ strong, to make a product 36% strong?

$$36\% \begin{cases} 23\tfrac{1}{3}\% = 63 \text{ parts} = 9 \text{ lb.} \\ 99\ \% = 12\tfrac{2}{3} \text{ parts} = ? \end{cases}$$

Then—63 parts : $12\frac{2}{3}$ parts :: 9 lb. : (x) $1\frac{5}{6}\frac{1}{3}$ lb. = 1 lb. 12 oz. 417 gr.

Problems.

398. A druggist has 400 Gm. of opium, 10% strong, 350 Gm., 12% strong. How much opium, 16% strong, should he add to a mixture of the 10% and the 12% opium to make a product 13% strong?

399. How much ammonia water, 28%, should be added to a mixture of 5 lb. of ammonia water, 10%, and 300 Gm., 8%, to make a product 15% strong.

400. In a laboratory there are three lots of solution of potassium iodide as follows:—400 Gm. of 5%, 200 Gm. of 12%, and 300 Gm. of 15%. How much potassium iodide must be dissolved in a mixture of the three lots to make a product 25% strong?

In Case the Quantity of Product Wanted is Specified, and Quantity of Each of the Ingredients is to be Calculated.

Problem.—How much cinchona, quinine-strength, 3.9%, and how much cinchona, 2.4%, must be used to make a product having a quinine-strength of 3%?

Solution.—

$$3\% \begin{cases} 2.4\% = .9 \times 10 = & 9 \text{ parts} = ? \\ 3.9\% = .6 \times 10 = & \underline{6} \text{ parts} = ? \end{cases}$$

$$15 \text{ parts} = 10 \text{ lb.}$$

If 6 parts and 9 parts are mixed, the product will be 15 parts. Then to make 15 parts of the product 9 parts of the cinchona, 2.4%, must be used; and from these 9 parts the quantity for 10 lb. may be found by proportion, weights being proportional to proportionate parts.

Thus— 15 parts : 9 parts : : 10 lb. : (x) 6 lb.

In like manner the quantity of the stronger cinchona may be calculated:

15 parts : 6 parts : : 10 lb : (x) 4 lb.

Proof.

$$\begin{array}{lcl} 9 \text{ lb.} \times 2.4\% & = & 21.6\% \text{ units.} \\ \underline{6} \text{ lb.} \times 3.9\% & = & \underline{23.4\%} \text{ units.} \\ 15 \text{ lb.} & & 45.0\% \text{ units.} \end{array}$$

$$45. \div 15 = 3\%$$

and

$$6 \text{ lb.} + 4 \text{ lb.} = 10 \text{ lb.}$$

Note.—It will be observed that the general proportion is—sum of the parts : parts of the ingredient : : weight of the mixture : x. x = weight of the ingredient.

Problems.

402. How many Gm. of colchicum, alkaloidal strength, .4%, and how many Gm. of the strength of .56%, must be used to make 20 Kgm. of product of an alkaloidal strength of .5%?

403. How many gr. of mercuric chloride must be added to how many gr. of mercuric chloride solution, 2% strong, to make 500 gr. of a solution which is 5% strong?

404. 5 lb. of opium containing 14% of morphine is wanted. How much 9% opium, how much 11%, and how much 15.4% may be used to make a mixture of required weight and strength.

In Case Quantity of Product Wanted, and also the Quantity of One or More Ingredients is Specified.

Problem.— 1000 Gm. of alcohol, 50% strong, is to be made from 100 Gm. of 80% alcohol, by the addition of 40% and 65% alcohol. How much of each of the latter two strengths should be used?

Solution.—

$$50\% \begin{cases} 40\% = 30 \text{ parts} = ? \\ 80\% = 10 \text{ parts} = 100 \text{ Gm.} \end{cases}$$

$$10 \text{ parts} : 30 \text{ parts} :: 100 \text{ Gm.} : (x) = 300 \text{ Gm.}$$

To reduce the 100 Gm. of 80% to the desired percentage 300 Gm. of 40% must be used. This will make 400 Gm. of mixture. But 1000 Gm. are wanted. 1000 Gm. — 400 Gm. = 600 Gm., which is the amount to be made by mixing 40% and 65% alcohol.

$$50\% \begin{cases} 40\% = 15 \text{ parts} = ? \\ 65\% = \underline{10} \text{ parts} = ? \end{cases}$$

$$25 \text{ parts} = 600 \text{ Gm.}$$

25 parts : 15 parts :: 600 Gm. : (x) 360 Gm. of 40%
and 25 parts : 10 parts :: 600 Gm. : (x) 240 Gm. of 65%.

Proof.

$$\begin{array}{lr} 100 \text{ Gm. of } 80\% = & 8000\% \text{ units.} \\ 300 \text{ Gm. of } 40\% = & 12000\% \text{ units.} \\ 360 \text{ Gm. of } 40\% = & 14400\% \text{ units.} \\ 240 \text{ Gm. of } 65\% = & 15600\% \text{ units.} \\ \hline 1000 \text{ Gm.} & 50000\% \text{ units.} \end{array}$$

$$50000 \div 1000 = 50[\%].$$

Calculating Doses for Children.

The rule most generally used is known as Dr. Young's Rule, and is as follows:

Multiply the adult dose by the fraction obtained by dividing the age of the child [in years] by its age plus 12.

Problem.—If the adult dose of the medicine is 5 gr., what is the dose for a child 4 years old?

Solution.—$4 \div (4 + 12) = \frac{4}{16} = \frac{1}{4}$; then 5 gr. $\times \frac{1}{4} = \frac{5}{4} = 1\frac{1}{4}$ gr.

Problem.—If the adult dose is $\frac{1}{8}$ gr., what is the dose for a child 2 years old?

Solution.—$2 \div (2 + 12) = \frac{2}{14} = \frac{1}{7}$; then $\frac{1}{8}$ gr. $\times \frac{1}{7} = \frac{1}{56}$ gr.

NOTE.—But children are very susceptible to narcotics, especially to opium; and of these medicines less than one-half the amount indicated by Young's Rule is given. Of cathartics, however, double the calculated dose is usually required.

CHAPTER IX.

CHEMICAL PROBLEMS.

Problems Based on Chemical Formulas.

Molecules.—It is a generally accepted theory that matter is not infinitely divisible, but that, when division has been carried to a certain extent, particles will be obtained which cannot be divided without destroying the chemical character of the substance. These particles have been called molecules. They are inconceivably small; but how small—of what volume, and of what weight—is not known*.

Atoms.—The molecule of hydrochloric acid is, therefore, a particle of hydrochloric acid which cannot be further divided into particles having the properties of hydrochloric acid. However, by chemical means, the particle can be divided into two dissimilar particles—hydrogen, and chlorin, each of which is different from the acid, the latter having been destroyed. The fact that such division is possible, indicates that molecules are composed of still smaller particles. These are called atoms. An atom may be defined as the smallest particle of an element known to exist in combination †.

Atomic Weights.—Of the size and actual weight of atoms no more is known than of the size and weight of molecules.

However, the *relative weights* of atoms have been determined with considerable accuracy. To illustrate: the weight of an

---

*According to calculations based upon the kinetic theory of gases, a molecule of hydrogen weighs about .000,000,000,000,000,000,000,004 Gm. But accuracy is not claimed for this result.

†When an element exists free, its smallest particle is a molecule. The molecules of most elements appear to contain two atoms; but mercury, zinc, and cadmium each contain but one atom in a molecule; while phosphorus, and arsenic each contain four atoms in the molecule.

atom of sulphur is not known; but it is known that an atom of sulphur weighs about twice as much as an atom of oxygen, and 31.83 times as much as an atom of hydrogen—whatever weight that is.*

It is to these relative weights that the term *atomic weights* is applied.

The atomic weights as usually given are referable to the weight of a hydrogen atom, this being expressed by unity—by 1.000.†

Accordingly the atomic weight of oxygen is 15.88, which means that an atom of oxygen weighs 15.88 times as much as an atom of hydrogen. The atomic weight of nitrogen is 13.93; that of sulphur is 31.83, etc.—A table of atomic weights is given on the last page.

[By some authorities the atom of oxygen with the weight of 16, [$O = 16$], is taken as the standard. The chief advantages claimed for the oxygen standard are: (1.) the atomic weights of a larger number of the elements are whole numbers; (2.) in atomic weight determinations it is impossible in case of most elements to make a direct comparison with hydrogen, while direct comparison with oxygen presents no special difficulties.]

Molecular Weights.—Molecular weight, like atomic weight is *relative*—not actual—weight. The standard for atomic weights is the standard for molecular weights as well. It follows then that the molecular weight of a compound is the weight of its molecule as compared with the weight of an *atom* of hydrogen;—that is, if the standard of $H = 1.000$ is employed. It follows also that the molecular weight will, in

---

*The unknown weight of the hydrogen atom is by some authorities referred to as the microcrith. The oxygen atom is then said to weigh 15.88 microcriths, the nitrogen atom, 13.93, etc.

†The weight of a hydrogen atom was selected as the standard because the atom of hydrogen weighs less than the atom of any other element.

every instance, be equal to the sum of the weights of the atoms in the molecule. Hence, in case of elements, the atomic weight may be calculated from the molecular weight; for mol. wt. ÷ no. of atoms in molecule = at. wt. And, on the other hand, if the molecular formula of a compound is known, and also the atomic weight of each of the elements in the compound, the molecular weight may be obtained by calculation.

Calculation of Molecular Formula.

The following data are necessary, and are, of course, determined experimentally:

1. The molecular weight of the compound.

2. The identity of the elements in the compound, and the atomic weights of these elements.

3. The proportion in which the component elements are present. [Expressed in parts by weight, usually in percentage.]

Problem.—Suppose the molecular weight of the compound has been found to be 90; and the percentage composition as follows:—carbon, 40%, hydrogen, $6\frac{2}{3}$%, oxygen, $53\frac{1}{3}$%. Assuming the atomic weight of hydrogen to be 1, carbon 12, and oxygen 16, what is the formula of the compound?

Process.—First calculate how many parts of each of the three elements would be present in 90 parts, 90 being the molecular weight:

$$100\% : 40\% :: 90 \text{ parts} : x \text{ (36 parts)}.$$
$$100\% : 6\tfrac{2}{3}\% :: 90 \text{ parts} : x \text{ (6 parts)}.$$
$$100\% : 53\tfrac{1}{3}\% :: 90 \text{ parts} : x \text{ (48 parts)}.$$

Then divide the parts for each of the elements by the atomic weight of that element. Thus—.

Carbon, 36 parts $\div$ 12 (at. wt.) = 3.
Hydrogen, 6 parts $\div$ 1 (at. wt.) = 6.
Oxygen, 48 parts $\div$ 16 (at. wt.) = 3.
The molecular formula is $C_3H_6O_3$.

Note.—The calculation is here simplified by use of approximate atomic weights. In practice the accurate atomic weights are employed.

Calculation of Molecular Weight from Molecular Formula.

As has been stated, the molecular weight of a compound must be determined experimentally before it becomes possible to deduce the molecular formula. But when the latter is known, the molecular weight may be calculated *from* the formula; for *the molecular weight is the sum of the weights of the atoms in the molecule.*

For instance:—The molecular weight of NaI is the atomic weight of Na = 22.88, plus the atomic weight of I = 125.89; hence is 148.77. The molecular weight of O_3 [Ozone] is the atomic weight of O = 15.88 taken 3 times; hence is, 47.64. The molecular weight of HNO_3 is the atomic weight of H = 1, plus the atomic weight of N = 13.93, plus 3 times the atomic weight of O = 15.88, which is 47.64; hence the molecular weight of HNO_3 is $1 + 13.93 + 47.64 = 62.57$.

Problem.—Calculate the molecular weight of H_2SO_4.

Solution.—

$$
\begin{aligned}
H_2 &= \mathit{1} \times 2 = 2 \\
S &= \mathit{32} \times 1 = 32 \\
O_4 &= \mathit{16} \times 4 = 64
\end{aligned}
$$

Mol. wt. of H_2SO_4 = 98*.

Note.—The numbers in italics are the atomic weights.

Problem.—

Calculate the molecular weight of $Na_2CO_3.10H_2O$.

Solution.—

$$\begin{array}{lclcl} Na_2 & = & \mathit{23} \times 2 & = & 46 \\ C & = & \mathit{12} \times 1 & = & 12 \\ O_3 & = & \mathit{16} \times 3 & = & 48 \\ 10\ H_2 & = & 10 \times \mathit{1} \times 2 & = & 20 \\ 10\ O & = & 10 \times \mathit{16} & = & 160 \\ \hline \end{array}$$

Mol. wt. of $Na_2CO_3.10H_2O = 286$*.

Problem.—Calculate the molecular weight of $(MgCO_3)_4.Mg(OH)_2.5H_2O$.

Solution.—Reducing the rational formula to an empirical formula we have $Mg_5C_4O_{19}H_{12}$.

And—

$$\begin{array}{lcl} Mg_5 & = \mathit{24} \times 5 = & 120 \\ C_4 & = \mathit{12} \times 4 = & 48 \\ O_{19} & = \mathit{16} \times 19 = & 304 \\ H_{12} & = \mathit{1} \times 12 = & 12 \\ \hline \end{array}$$

Mol. wt. of $(MgCO_3)_4.Mg(OH)_2.5H_2O = 484$*.

Problems.

411. Calculate the molecular weight for (a.) H_2O; (b.) NaOH; (c.) $HgCl_2$; (d.) $C_{10}H_8$.

412. For—(a.) $FeSO_4.7H_2O$; (b.) $Fe_2(PH_2O_2)_6$; (c.) $HC_3H_5O_3$. (d.) $Al_2K_2(SO_4)_4.24H_2O$.

413. For—(a.) $C_{12}H_{22}O_{11}$; (b.) $CHCl_3$.

414. For—$C_{20}H_{24}N_2O_2.3H_2O$ (Quinine).

415. For—$(C_{21}H_{22}N_2O_2)_2H_2SO_4.5H_2O$ (Strychnine Sulphate).

---

*Approximate atomic weights are here used. Employing the at. weights of F. W. Clarke [see table] the mol. wt. of $H_2SO_4 = 97.35$; that of $Na_2CO_3.10H_2O = 284.1$; and that of $(MgCO_3)_4.Mg(OH)_2.5H_2O = 481.82$.

Note.—Remember that a subscript following a symbol applies to that symbol only; that a subscript following parentheses multiplies all within the parentheses; and that a coefficient preceding a formula multiplies the entire formula. If, however, the coefficient precedes only part of a formula, only the portion which follows is affected by the coefficient. Thus in the formula $K_4Fe(CN)_6.3H_2O$, the subscript 4 multiplies K; the subscript 6 multiplies C and N; and the coefficient 3 multiplies H_2O.

Calculation of the Percentage Composition of a Compound from its Formula.

Problem.—Calculate the percentage composition of Fe_2O_3.

Solution.—

$$
\begin{aligned}
Fe_2 &= \mathit{56} \times 2 = 112 \\
O_3 &= \mathit{16} \times 3 = 48 \\
\hline
\end{aligned}
$$

$$\text{Mol. wt. of } Fe_2O_3 = 160^*.$$

Atomic weights, and hence also molecular weights, may be considered as *parts by weight.* It follows then that 160 parts of Fe_2O_3 contain 112 parts of Fe. From these data the percentage of Fe may be calculated by proportion in the usual manner:

The three known terms are, 160 parts, 112 parts, and 100%. The answer is to express %. Hence—

$$: \quad :: \quad 100\% \quad : \quad x$$

The answer is to be smaller than 100%, because a part must be smaller than the whole. Hence—

$$160 \text{ parts} : 112 \text{ parts} :: 100\% : x$$

$$x = 70\% = \% \text{ of Fe.}$$

In like manner the percentage of O may be calculated:

$$160 \text{ parts} : 48 \text{ parts} :: 100\% : x$$

$$x = 30\% = \% \text{ of O.}$$

Problem.—What is the percentage composition of $C_6H_{12}O_6$?

---

*In this, and in the succeeding examples of this sub-chapter, approximate atomic weights are employed; while in the calculations of the sub-chapter which follows, the atomic weights according to Clark are used.

Solution.—
$$\begin{aligned} C_6 &= \mathit{12} \times 6 = 72 \\ H_{12} &= \mathit{1} \times 12 = 12 \\ O_6 &= \mathit{16} \times 6 = 96 \\ & \overline{180} \end{aligned}$$

Then—

180 parts : 72 parts : : 100% : x
x = 40% = % of C.
180 parts : 12 parts : : 100% : x
x = $6\frac{2}{3}$% = % of H.
180 parts : 96 parts : : 100% : x
x = $53\frac{1}{3}$% = % of O.

Problems.

418. Calculate the percentage composition of—(a.) H_2O; (b.) H_2O_2; (c.) H_3PO_4; (d.) $C_{12}H_{22}O_{11}$; (e.) $C_{20}H_{24}N_2O_2.3H_2O$ [quinine].

THE PERCENTAGE-CONTENT OF ONLY ONE ELEMENT OR GROUP OF ELEMENTS IS REQUIRED.

Problem.— What is the percentage of iron in $FeSO_4$. $7H_2O$?

Solution.—
$$\begin{aligned} Fe &= \mathit{56} \times 1 &= 56 \\ S &= \mathit{32} \times 1 &= 32 \\ O_4 &= \mathit{16} \times 4 &= 64 \\ 7H_2 &= 7 \times \mathit{1} \times 2 &= 14 \\ 7O &= 7 \times \mathit{16} &= 112 \\ \text{Mol. Wt. of } FeSO_4.\ 7H_2O &&= 278 \end{aligned}$$

Then— 278 parts : 56 parts : : 100% : x
x = 20.1% = % of Fe.

Problem.—Calculate the percentage of water of crystallization in $Na_2CO_3.10H_2O$.

Solution.—The molecular weight of $Na_2CO_3.10H_2O$ is 284. The molecular weight of H_2O is 18; hence the relative weight for the ten molecules is 180.

In other words, 284 parts of $Na_2CO_3.10H_2O$ contain 180 parts of water.

Then— 284 parts : 180 parts : : 100% : x (63.3%).

Problems.

421. What % of anhydrous $FeCl_3$ in $FeCl_3.6H_2O$?

422. What % of Fe in $FeCl_3.6H_2O$?

423. What % of C in CH_4?

424. What % of I in CHI_3[iodoform].

425. What % of I in C_4NHI_4[iodol].

426. What % of arsenic in realgar—an arsenical ore of the composition As_2S_2?

427. What % of zinc in sphalerite—a zinc ore of the composition of ZnS?

428. What % of water of crystallization in $FeSO_4.7H_2O$?

429. In making dried sodium carbonate the crystallized sodium carbonate is heated until it has lost one-half its weight. What % of water of crystallization remains in the dried carbonate?

Solution.—Mol. wt. of $Na_2CO_3.10H_2O = 284$.

If the weight is reduced to one-half, the molecular weight of the product must be $284 \div 2 = 142$. The molecular weight of anhydrous $Na_2CO_3 = 105$. Then $142 - 105 = 37$ = weight of water in the molecule of dried carbonate.

And 142 parts : 37 parts : : 100% : x (26%).

[Answer is not exactly correct, approximate weights having been used.]

430. How many molecules of water of crystallization in the dried sodium carbonate (U. S. P.)?

Solution.—If the molecular weight is one-half that of the crystallized carbonate, there are about 37 parts of water present; for 142 — 105 = 37. And 37 ÷ 18 (mol. wt. of H_2O) = 2 +. So a little over two molecules are present [according to the figures used]; and the formula $Na_2CO_3.2H_2O$ is nearly correct for the official dried carbonate.

Calculations Based on Chemical Reactions.

Atomic weights are relative weights, and for arithmetical purposes may be thought of as parts by weight. This being true of atomic weights, it must be true also for molecular weights and for multiples of molecular weights.

By the equation—

$Zn + H_2SO_4 = ZnSO_4 + H_2$ it is indicated that an atom of zinc requires a molecule of absolute sulphuric acid in order to make a molecule of zinc sulphate, and two atoms [a molecule] of hydrogen.* Now if the atomic weight of Zn is 64.9, and the molecular weight of H_2SO_4 is 97.35, it follows that 64.9 parts by weight of Zn will require 97.35 parts by weight of H_2SO_4. And if the molecular weight of $ZnSO_4$ is 160.25, and the atomic weights of H is 1, 160.25 parts by weight of $ZnSO_4$ and 2 parts by weight of H will be the products of the reaction. Thus—

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$
$$64.9 + 97.35 = 160.25 + 2.$$

Problem.—How many Gm. of abs. H_2SO_4 is required to convert 50 Gm. of Zn into Zn SO_4?

*In order that the reaction may occur as shown in the equation it is necessary that the acid used be diluted with considerable water, concentrated acid giving rise to other products, including SO_2 and H_2S. However, the water, though necessary, is the same on the product-side of the equation as on the factor-side, and hence does not enter into the calculations.

Solution.—Since atomic and molecular weights may be considered as indicating parts by weight, the problem may be stated as follows:—if 64.9 parts of Zn require 97.35 parts of H_2SO_4, 50 Gm. of Zn will require how many Gm. of H_2SO_4? The parts, being parts by weight, are proportional to Gm., and the answer may be found by proportion in the usual manner, as follows:

The answer is to express weight [Gm.]; hence the known term expressing weight must be the third.

: :: 50 Gm. : x

The answer is to be larger than 50 Gm., because the answer is to give the amount of H_2SO_4, and as it requires 97.35 parts of acid for 64.9 parts of Zn; i.e., it requires *more* acid than Zn., the answer will be larger than 50 Gm.

Hence—

64.9 parts: 97.35 parts :: 50 Gm. : x (75 Gm).

Problem.—How many Gm. of Zn will 75 Gm. of absolute H_2SO_4 convert into Zn SO_4?

Solution.—Weight is asked for; hence the known term expressing weight must be the third. The answer is to be smaller than 75 Gm., because it requires less Zn than H_2SO_4. Hence—

97.35 parts : 64.9 parts : : 75 Gm. : x (50 Gm).

In like manner—by proportion—the amount of $ZnSO_4$ formed may be calculated, as may also the amount of H evolved. Again, the amount of one of the products might be given. From it the amount of the other products may be calculated; also the amount of Zn, and the amount of H_2SO_4 required. In short, *if the quantity for any one member of an equation is given, the quantity for any other member may be found by proportion.*

It will be seen by close inspection that twelve distinct prob-

lems may be based on the equation given; and in case of equations of more than four members, the number of possible problems is correspondingly larger. Yet any and all may be solved by proportion, no specific rules being necessary. However, in order that there may be no mistake in selecting the terms for the proportion, the following procedure is recommended:

1. Write the equation for the reaction on which the problem is to be based.

2. Select the two members of the equation which figure in the problem; namely, (1.) the compound [or element] the quantity of which is *given* in the problem, and (2.) the compound [or element] the quantity of which is *sought.* Draw a line under each of the members of the equation thus selected; also indicate for which one the quantity is given and for which one it is sought.

3. Calculate the reacting weight for each of these two members of the equation, writing the reacting weight under the lines.

[The term reacting weight is here used to indicate the atomic weight, molecular weight, or multiple of these, as required by the equation. If, in the latter, the molecule is multiplied by a coefficient, the molecular weight must be multiplied by the same coefficient, and the product used in the proportion.]

4. Select the third term. When quantity is asked for, the quantity given in the problem must constitute the third term. However, since the other values are weights—reacting weights, considered as parts by weight—the quantities must be in weight; for volumes are not proportional to parts by weight.

5. Select the second term.—Reacting weights [parts by

weight] are *directly* proportional. Hence the answer will be larger than the third term if the reacting weight of the substance, the quantity of which is sought, exceeds the reacting weight of the substance, the quantity of which is given. Or, in other words, the reacting weight of the substance, the quantity of which is sought, must be the second term.

6. Then the reacting weight of the substance, the quantity of which is given, must be the first term, and the general proportion will be as follows:

Reacting weight of substance whose quantity is given *is to* the reacting weight of the substance whose quantity is sought *as* the quantity given *is to* the quantity sought. This must be so because the two values are *directly* proportional.

Application of Rule.

Problem.—How many Gm. of Zn are required to generate 30 Gm. of H?

Solution.—

1. Equation: $Zn + H_2SO_4 = H_2 + ZnSO_4$.
2. Members required: $\underset{\textit{sought}}{Zn} + H_2SO_4 = \underset{\textit{given}}{H_2} + ZnSO_4$.
3. Reacting weights required: $\underset{\substack{\textit{sought}\\64.9}}{Zn} + H_2SO_4 = \underset{\substack{\textit{given}\\2}}{H_2} + ZnSO_4$.
4. Third term selected:

$$: \quad :: \quad 30 \text{ Gm.} \quad : \quad x.$$

5. To generate 2 parts of H requires *more* than 2 parts of Zn; therefore the answer must be larger than the third term.

Then—

2 parts : 64.9 parts :: 30 Gm. : x (973.5 Gm.)

That is—

React. wt. of H : React. wt. of Zn :: wt. of H. : wt. of Zn.

It will be seen that the H and Zn alternate. This alternation of substances in the proportion—made necessary by the fact that the two values are *directly* proportional—may serve as proof that the first and second terms have been correctly placed.

Problem.—How many Gm. of ferric sulphate are required to make 100 Gm. of ferric hydroxide?

Solution.—

$$\text{Equation: } \underset{\substack{\textit{sought}\\ 397.05}}{Fe_2(SO_4)_3} + 6NH_4OH = \underset{\substack{\textit{given}\\ 212.28}}{2Fe(OH)_3} + 3(NH_4)_2SO_4.$$

Then 212.28 parts : 397.05 parts :: 100 Gm. : x (187 Gm.)

Re. Wt. of $Fe(OH)_3$: Re. Wt. of $Fe_2(SO_4)_3$ :: Wt. of $Fe(OH)_3$: Wt. of $Fe_2(SO_4)_3$.

Notice that the reacting weight of $Fe(OH)_3$ is twice its molecular weight [$106.14 \times 2 = 212.28$]; the equation showing that one molecule of $Fe_2(SO_4)_3$ will make two molecules of $Fe(OH)_3$.

NOTE.—On comparing the amounts given in the working formulas of text-books with the amounts of the factors as calculated from equations, great discrepancies will often be noticed. Thus, the amount of iron used in making FeI_2 is greatly in excess of the amount required by the equation. In like manner, ammonia water, when used to precipitate ferric salts, is used in considerable excess. Practical experience has proven such excesses necessary. [For explanations the student is referred to the standard works on theoretical chemistry, especially to the chapters on mass action, on the ion theory, and on chemical equilibrium.] However, even in these instances the quantities as calculated from the equation, form a basis for the working formula.

Problems.

436. How much lime (CaO) can be made from 100 Gm. of marble ($CaCO_3$)?

Equation: $CaCO_3 + \text{heat} = CaO + CO_2$.

437. How much carbon dioxide (CO_2) is formed at the same time?

438. How much absolute H_2SO_4 is required to neutralize 50 Gm. of absolute NaOH?

Equation: $2\ NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O$.

439. How much Na_2SO_4 is formed?

440. How much water is formed as a by-product?

441. How much $Ca\ (PH_2O_2)_2$ is required to make 2 oz. of KPH_2O_2?

Equation: $Ca(PH_2O_2)_2 + K_2CO_3 = 2KPH_2O_2 + CaCO_3$.

442. How much $CaCO_3$ is formed as a by-product?

443. How many Gm. of silver nitrate can be made from 100 Gm. of silver?*

Equation: $3\ Ag + 4HNO_3 = 3\ AgNO_3 + NO + 2H_2O$.

444. How much NO will be evolved?

445. How much absolute HNO_3 will be used for the purpose?

446. How much dried alum can be made from 50 Gm. of crystallized alum?

NOTE.—The dried alum is alum minus the water of crystallization: $Al_2K_2(SO_4)_4.24H_2O = Al_2K_2(SO_4)_4 + 24H_2O$.

447. Hydriodic acid may be made by the interaction of potassium iodide and tartaric acid, as follows:

$$KI + H_2C_4H_4O_6 = HI + KHC_4H_4O_6.$$

How much potassium iodide, and how much of tartaric acid, is required to make 50 Gm. of the hydriodic acid?

---

*In balancing oxidation and reduction equations employ Johnson's rule.

448. One pound of baking powder is to contain 9 oz. of cream of tartar, and enough baking soda for neutralization*. How much of the latter is required?

Equation:

$KHC_4H_4O_6 + NaHCO_3 = KNaC_4H_4O_6 + CO_2 + H_2O.$

449. How much carbon dioxide would a pound of this baking powder yield?

450. A druggist has use for 200 gr. of lithium citrate. He has none in stock, but has the carbonate. So he decides to make the citrate from the carbonate by saturation with citric acid. How much of the carbonate should he use?

Equation:

$3Li_2CO_3 + 2H_3C_6H_5O_7 = 2L_3C_6H_5O_7 + 3CO_2 + 3H_2O.$

451. According to the pharmacopœia, mercuric oleate is made from 200 Gm. of mercuric oxide, and 800 Gm. of oleic acid. How much oleic acid is required to make the salt—mercuric oleate—and how much of the acid is present in the finished product as a diluent or vehicle?

Equation: $HgO + 2HC_{18}H_{33}O_2 = Hg\ (C_{18}H_{33}O_2)_2 + H_2O.$

452. A druggist desires to make quinine bisulphate from the normal sulphate. How much absolute H_2SO_4 would be required by 100 Gm. of the normal salt?

Equation: $(C_{20}H_{24}N_2O_2)_2H_2SO_4.7H_2O + H_2SO_4 + 7H_2O = 2C_{20}H_{24}N_2O_2H_2SO_4.7H_2O.$

453. How much $SrCO_3$ is required to make 1 oz. of $Sr(C_3H_5O_3)_2.3H_2O$?

Equation: $SrCO_3 + 2HC_3H_5O_3 = Sr(C_3H_5O_3)_2 + CO_2 + H_2O.$

---

*The rest is corn starch.

454. How much absolute $HC_3H_5O_3$ is required?

Calculation Based on Reaction, but Involving Also Percentage Solutions.

From the equation, $3Hg + 8HNO_3 = 3Hg(NO_3)_2 + 2NO + 4H_2O$, the amount of *absolute* HNO_3 required to dissolve a given amount of Hg can be calculated by proportion. However, the acid which is actually used in the operation is not absolute HNO_3, but is an aqueous solution of the latter, 68% strong. A second calculation, in which it is determined how much 68% acid would be equivalent to [that is, would contain] the amount of absolute HNO_3 found by proportion, is therefore necessary, if the answer is to form the basis for practical work.

Example.—How many Gm. of nitric acid, 68% strong, are required to dissolve 20 Gm. of mercury as mercuric nitrate?

$$\underset{\substack{given \\ 595.5}}{3Hg} + \underset{\substack{sought \\ 500.56}}{8HNO_3} = 3Hg(NO_3)_2 + 2NO + 4H_2O.$$

595.5 parts : 500.56 parts :: 20 Gm. : x (16.825 Gm.)

The answer indicates the amount of *absolute* HNO_3; and from this answer the amount of 68% acid containing 16.825 Gm. of absolute HNO_3, may be found by a second proportion. See page 80 et seq.

For this second proportion the three known terms are—68%, 100% [the % of the abs. HNO_3], and 16.825 Gm. The answer is to express weight. Hence—

: :: 16.825 Gm. : x

The answer is to be *larger* than 16.825 Gm., because the question is, how much of a weaker acid is equivalent to 16.825 Gm. of absolute HNO_3. Hence—

68% : 100% :: 16.825 Gm. : x (24.74 Gm.)

Accordingly, 24.74 Gm. of official nitric acid is required to dissolve 20 Gm. of mercury.

Note.—As has been stated before, dividing the divisor is equivalent to multiplying the dividend. It follows then that (16.825 Gm. $\times$ 100) $\div$ 68 = 16.825 Gm. $\div$ (68 $\div$ 100). In other words, the amount of weaker acid may be found by dividing the amount of absolute acid by the percentage strength of the weaker acid, expressed in hundredths. Thus—

$$16.825 \text{ Gm.} \div .68 = 24.74 \text{ Gm.}$$

See page 76.

Problem.—How many lb. of potassium acetate can be made from 50 lb. of acetic acid, 36% strong?

Remarks.—This problem may be solved in two ways: either the absolute acid in 50 lb. of the 36% acid may be calculated, and this amount of absolute acid placed as the third term, in which case the fourth term will be the answer desired; or, the 50 lb. [of 36% acid] may be use as the third term, giving as the fourth term the amount of a 36% solution of potassium acetate, from which, by a subsequent calculation, the amount of [absolute] potassium acetate may be found.

Solution, the first-mentioned process being used.—

$$100\% \; : \; 36\% \; :: \; 50 \text{ lb.} \; : \; x \; (18 \text{ lb.}),$$

showing that the 50 lb. of 36% acid contain 18 lb. of absolute acid.

The problem has thus been simplified to—How much $KC_2H_3O_2$ can be made from 18 lb. of $HC_2H_3O_2$?

Equation:

$$\underset{\substack{given \\ 59.56}}{HC_2H_3O_2} + KHCO_3 = \underset{\substack{sought \\ 97.38}}{KC_2H_3O_2} + CO_2 + H_2O.$$

Then— 59.56 parts : 97.38 parts :: 18 lb. : x

$x = 29.4$ lb. = wt. of $KC_2H_3O_2$.

Problem.—How many Gm. of $Na_2CO_3.10H_2O$ must be used to make 500 Gm. of 5% solution of NaOH?

Solution.— 100% : 5% : : 500 Gm. : x (25 Gm.), showing that the 500 Gm. of solution contain 25 Gm. of NaOH.

Equation:

$$\underset{\substack{sought \\ 284.1}}{Na_2CO_3.10H_2O} + Ca(OH)_2 = \underset{\substack{given \\ 79.52}}{2NaOH} + CaCO_3 + 10H_2O$$

79.52 parts : 284.1 parts : : 25 Gm. : x (89.3 Gm.)

Problems.

459. A druggist desires to prepare 250 Gm. of dil. HBr (10%) by the tartaric acid method. How much KBr, and how much $H_2C_4H_4O_6$ are required?

Equation: $KBr + H_2C_4H_4O_6 = HBr + KHC_4H_4O_6$.

460. HCN may be made extemporaneously from AgCN and HCl. How much hydrochloric acid, 31.9% strong, would be required by 1 oz. of silver cyanide?

Equation: $AgCN + HCl = AgCl + HCN$.

461. How many gr. of dil. HCN (2% strong) would be produced?

462. How many Gm. of ammonia water, 28% strong, would be required to precipitate all the iron in a 100 Gm. of 15% solution of $Fe_2(SO_4)_3$?

Equation: $Fe_2(SO_4)_3 + 6NH_3 + 6H_2O = 2Fe(OH)_3 + 3(NH_4)_2SO_4$.

Notes.—The stronger ammonia water contains 28% of NH_3—not of NH_4OH. Hence the division of NH_4OH into $NH_3 + H_2O$ in the equation.

In practice a decided excess of precipitant is required.

PROBLEMS INVOLVING ALSO REDUCTION OF VOLUME TO WEIGHT AND VICE VERSA.

Problem.—How many grains of Zn would be converted into $ZnCl_2$ by 200 c.c. of hydrochloric acid, sp. gr., 1.16, strength, 30%?

Solution.— 200 c.c. [$\times$ 1.16] = 232 Gm.

100% : 30% : : 232 Gm. : x (69.6 Gm. of abs. HCl).

Equation:— $Zn + 2HCl = ZnCl_2 + H_2$.

Zn	2HCl
sought	*given*
64.9	72.36

Then—

72.36 parts : 64.9 parts : : 69.6 Gm. : x (62.4 Gm. of Zn.)

Problems.

464. How many gr. of Li_2CO_3 would be dissolved as LiCl by 1 f℥ of hydrochloric acid, sp. gr., 1.163, strength, 31.9%?

Equation: $Li_2CO_3 + 2HCl = 2LiCl + CO_2 + H_2O$.

465. How many c.c. of nitric acid, sp. gr., 1.414, strength, 68%, can be made from 600 Gm. of $NaNO_3$?

Equation:—$NaNO_3 + H_2SO_4 = NaHSO_4 + HNO_3$.

466. How many c.c. of sulphuric acid, sp. gr., 1.835, strength, 92.5%, would be required by the 600 Gm. of $NaNO_3$?

467. How many Gm. of bromine are required to make 500 c.c. of syrup of ferrous bromide, sp. gr., 1.35, strength, 10%?

Equation: $Fe + Br_2 = FeBr_2$.

468. How many f℥ of ammonia water, sp. gr., .9, strength, 28%, could be neutralized with 500 c.c. of acetic acid, sp. gr., 1.048, strength, 36%?

Equation: $NH_3.H_2O + HC_2H_3O_2 = NH_4C_2H_3O_2 + H_2O$.

NOTE.—The stronger ammonia water contains 28% of NH_3 — not of NH_4OH.

CHAPTER X.

REDUCING VOLUMES OF GASES TO WEIGHTS AND VICE VERSA.

It has been determined that at normal pressure and temperature, 22.39 L. of any gas, without exception, will weigh the molecular weight of the gas expressed in Grammes*. Thus,

22.39 L. of H	weigh 2 Gm.	2 atoms in the molecule.
22.39 L. of O	weigh 31.76 Gm.	
22.39 L. of N	weigh 27.86 Gm.	
22.39 L. of CO_2	weigh 43.66 Gm.	
22.39 L. of NH_3	weigh 16.93 Gm.	
	etc.	

This constant is of practical importance, as by its use the weight of any volume of any gas—or the volume of any weight—may be calculated by proportion.

As the weights and volumes are *directly* proportional—4 Gm. of H measuring twice as much as 2 Gm.—the general proportion for the determination of weight from volume would be:

22.39 L. : observed vol. in L. : : mol. wt. of gas in Gm. : x

x = wt. in Gm. of observed volume.

And the general proportion for the calculation of the volume of a definite weight of any gas would be:

mol. wt. of gas in Gm. : observed wt. in Gm. :: 22.39 L. : x

x = vol. of gas in L.

The general rule for the statement of the proportion may be used, as in the following examples.

---

*Upon this observed fact is based Avogadro's hypothesis: All gases and vapors, without exception, contain, in the same volume, the same number of molecules.

Problem.—What is the volume of 500 Gm. of oxygen?

Solution.—Mol. wt. of O = $15.88 \times 2 = 31.76$.

Then the three known terms for the proportion are—31.76 Gm., 500 Gm., and 22.39 L.

The answer is to express volume. Hence—

: : : 22.39 L. : x.

The values being directly proportional, and the weight for which the volume is to be found being *larger* than the weight for which the volume is known [the molecular weight, expressed in Gm.] the answer will be *larger* than the third term. Hence—

31.76 Gm. : 500 Gm. : : 22.39 L. : x (352.487 L.)

Problem.—What is the weight of 50 L. of NH_3?

Solution.—Mol. weight of $NH_3 = 16.93$.

Then the three known terms are—16.93 Gm., 50 L., and 22.39 L.

The answer is to express weight. Hence—

: : : 16.93 Gm. : x

The answer is to be larger than the third term. Hence—

22.39 L. : 50 L. : : 16.93 Gm. : x (37.8 Gm.)

Problems.

471. What is the volume of 1 Kg. of O? of 50 Gm. of CO_2? of 30 Gm. of H_2S? of 5 Gm. of Cl?

472. What is the weight of 50 L. of SO_2? of 10 L. of N_2O (laughing gas)? of 1 Cong. of O? of 300 c.c. of H?

Note.—Oxygen, chlorine, and hydrogen have two atoms in the molecule; hence the molecular weight is, for each of these elements, double the atomic weight.

EFFECT OF VARIATION IN PRESSURE ON THE VOLUME OF A GAS.

When the pressure upon a gas is increased, the volume of the gas is found to decrease correspondingly. If the pressure is doubled, the volume of the gas is thereby reduced to one-half the initial volume; if the pressure is tripled, the volume of the gas is reduced to one-third; if the pressure is reduced to one-half the initial pressure, the volume of the gas becomes twice the initial volume; etc.

Boyle's Law.—The relation of pressure to volume is stated by Boyle as follows: With the temperature constant, the volume of any given weight of any gas varies inversely as the pressure upon it.

It follows then that if the volume has been observed at any given pressure, the volume which the gas would occupy at any other pressure may be calculated by proportion.

Problem.—The NO gas, evolved from a certain amount of ethyl nitrite, measures 60 c.c. at a pressure of 744 mm.* How much would it measure at 760 mm.?

Solution.—Volume is asked for.

Hence—

: :: 60 c.c. : x

The values being inversely proportional, the NO would measure *less* at 760 mm. than at 744 mm. The answer is therefore to be *smaller* than the third term. Hence—

760 mm. :: 744 mm. :: 60 c.c. : x (58.73 c.c.)

---

*Note.—Pressure of gases is expressed in units of length, the expression having reference to the height of a column of mercury which will have an equal pressure. Thus, a pressure of 760 mm. means a pressure capable of supporting (hence equai to) a column of mercury 760 mm. high. 760 mm. is the atmospheric pressure under standard conditions; and is known as normal pressure, or as one atmosphere. Two asmospheres would therefore equal 760 mm × 2.

Problems.

474. A Liter of ammonia gas at normal pressure, would measure how much at a pressure of two atmospheres?

475. A quantity of CO_2, which measures 84.5 c.c. at 751 mm., will measure how much at normal pressure?

476. A quantity of O, measuring 3 Cong. at 760 mm., would measure how much at 1.520 M.?

477. What would be the volume of 3 Gm. of SO_2 at 748 mm.

Note.—Remember that the constant, 22.39 L., is correct for normal pressure only.

478. What is the weight of 500 c.c. of Cl, measured at a barometric pressure of 752 mm.

Note.—When a gas is collected over a liquid, as N_2O over water, the pressure of the gas is equal to the atmospheric pressure—i. e., barometric pressure.

Effect of Variation of Temperature on the Volume of a Gas.

The standard temperature for measuring gases is 0°C. If the volume is taken at a different temperature [for sake of convenience], the volume at 0°C. must be calculated from the observed volume before the constant, 22.39 L., can be made use of.

With the pressure remaining unchanged, the volume of a gas varies directly as its absolute temperature*.

By absolute temperature is meant temperature reckoned from 273°C. below 0°C. In other words, the zero of absolute temperature is—273°C. It follows then that tempera-

*See Law of Charles;—not *exactly* true for all gases.

†For directions for adding a positive quantity to a negative quantity (for instance, 273°C. to — 20°C.) See page 151 et seq.

ture in °C. may be reduced to absolute temperature by adding 273°†. Thus, 15°C. is 273 + 15 = 288°C. absolute temperature; and 100°C. is 273 + 100 = 373°C. absolute temperature.

Problem.—A pharmacist in assaying Spt. of Nitrous Ether has obtained a volume of NO gas measuring 56 c.c. at a temperature of 22°C. What is the volume of the gas at 0°C.?

Solution.— 22°C. = 273 + 22 = 295°C. abs. temp.
0°C. = 273 + 0 = 273°C. abs. temp.

The three known terms are: 295°C. [absolute temperature at which volume was observed], 273°C [absolute temperature at which volume is wanted], and 56 c.c. [observed volume].

The answer is to express volume. Hence—

: : : 56 c.c. : x

As the volume varies *directly* with the temperature; and as the temperature at which the volume is wanted is *lower* than the temperature at which the volume is known, the answer must be *smaller* than the third term. Hence—

295°C. : 273°C. : : 56 c.c. : x (51.8 c.c.)

The general proportion would be:

Absolute temperature at which volume was observed *is to* absolute temperature at which volume is wanted [273°C. + 0°C. = 273°C.] *as* observed volume *is to* x*.

Problems.

480. A quantity of CO_2 measures 35 c.c. at 20°C. What will it measure at 0°C.?

20°C

*It will be seen that a gas expands $\frac{1}{273}$ of its volume for an increase in temperature of 1°C.; and that it contracts $\frac{1}{273}$ of its volume for a decrease in temperature of 1°C.; in short, that the coefficient of expansion of any gas is $\frac{1}{273}$, or, decimally, .003665.

481. A quantity of hydrogen measures 5 L. at 23°C. What would be its volume at 0°C.? What at 50°C.? What at 100°C.?

482. A quantity of NO measures 60 c.c. at a pressure of 750 mm., and at a temperature of 20°C. What would be its volume at normal pressure and temperature.

Solution.— 760 mm. : 750 mm. :: 60 c.c. : x
x = 58.68 c.c. = vol. at norm. pressure.

Then— 273 + 20°C. : 273 + 0°C :: 58.68 c.c. : x
x = 54.67 c.c. = vol. at norm. pressure and temp.

483. What is the *weight* in Gm. of 60 c.c. of NO gas, measured at a barometric pressure of 750 mm., and at a temperature of 20°C.?

Solution.—Having found the volume of the gas at normal pressure and temperature, as shown in the preceding example, we calculate the *weight* of that volume [in this case, 54.67c.c.] of NO thus:

22.39 L. : .05467 L. : 29.81 Gm. [mol. wt. of NO] : x
x = .0729 Gm.

484. How much $C_2H_5NO_2$[ethyl nitrite] is indicated by 60 c.c. of NO at a pressure of 75 mm., and at a temperature of 20°C. ?

Solution.—Having calculated the *weight* of the NO, we calculate the amount of $C_2H_5NO_2$ required to produce the weight [in this case, .0729 Gm.] of NO gas.

Equation:

$$\underset{\substack{\textit{sought}\\ 74.49}}{C_2H_5NO_2} + KI + H_2SO_4 = \underset{\substack{\textit{given}\\ 29.81}}{NO} + C_2H_5OH + KHSO_4 + I.$$

Then—
29.81 parts : 74.49 parts :: .0729 Gm. : x(.182 Gm.)

485. How many c.c. of CO_2, at normal pressure, and at a temp. of 25°C., would be generated from .5 Gm. of $NaHCO_3$?

Equation:—$2NaHCO_3 + H_2SO_4 = Na_2SO_4 + 2CO_2 + 2H_2O$.

486. How many L. of Hydrogen [pressure, 748 mm., temp., 20°C.] could be made from 5 Gm. of Zinc?

487. How much $KClO_3$ is required to generate 25 L. of O.?
Equation:—$2KClO_3 = 2KCl + 3O_2$.

Note.—If pressure and temperature are not given, normal pressure and temperature are understood.

488. How much NH_4NO_3 is required to make 10 gallons of N_2O [laughing gas]?

Equation:—$NH_4NO_3 = N_2O + 2H_2O$.

489. How much NH_4NO_3 is required to make enough N_2O to fill a 10 gallon tank, the temperature being 20°C., and the barometric pressure, 750 mm.?

490. A certain quantity of baking powder yielded 70 c.c. of CO_2;—temp., 20°C., pressure, 748 mm. How much $NaHCO_3$ did the quantity of baking powder contain?

Equation:—$NaHCO_3$ + acid = CO_2 etc.

491. How many c.c. of HCl gas in 10 c.c. of the liquid acid, sp. gr., 1.163, strength, 31.9%?

492. How many c.c. of ammonia water, sp. gr., .96, strength, 10%, would contain 5L. of NH_3 gas?

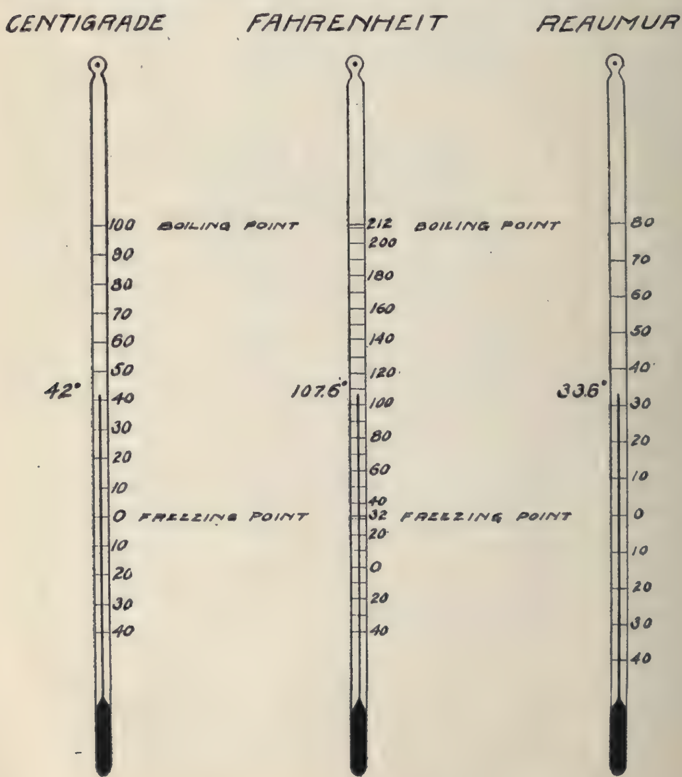
CHAPTER XI.

THERMOMETER SCALES.

On a Centigrade thermometer the temperature of melting ice [freezing point of water] is zero; and the temperature of steam, at normal pressure [boiling point of water], is 100.

On a Fahrenheit thermometer the temperature of melting ice is 32 above zero; and the temperature of steam, at normal pressure, is 212.

On a Reaumur thermometer the temperature of melting ice is zero; and that of steam, at normal pressure, is 80.



On all three thermometers the graduation is continued above the boiling point, and below the zero point.

Degrees below zero, on any scale, is expressed as a negative quantity, the minus sign being placed before the number; thus, —45°., which means 45° below zero. If the minus sign is absent, the number is *understood* to be a positive number, and to denote degrees above zero.

Centigrade to Fahrenheit.

It will be seen that 100°C. = 180°F. = 80°R.; and hence that 1°C. = 1.8°F. = .8°R.

Problem.—Convert 60°C. into °F.

Solution.—Since 1°C. = 1.8°F., 60°C. = 60° × 1.8 = 108°F. But since 60°C. means 60° above the freezing point, the 108°F. must be counted from that same point; and as the freezing point is marked 32 on the F. scale, 32 must be added to 108 in order to get the reading counting from zero F. Accordingly, 108° + 32° = 140°; and 60°C. = 140°F. Whence the rule—

$$(°C. \times 1.8) + 32 = °F.$$

Problem.—Convert —25°C. into °F.

Solution.— —25 × 1.8 = —45 [Remember that when a negative quantity is multiplied by a positive quantity, the product is a negative quantity.] It will thus be seen that 25 divisions on the C. scale equal 45 on the F. scale. But since the freezing point on the F. scale is 32° above zero, and since the °C. are counted from the freezing point, the temperature of —25°C. would be —45° + 32; *which means that the reading would be 32° higher on the F. scale than —45°*, hence would be [—45 + 32] — 13°F.

The rule for adding a positive quantity to a negative quantity is as follows: Subtract the smaller number from the

larger, and read the remainder with the sign of the la[illegible] number. Thus, $-10 + (+32) = +22$; $-42 + (+3[illegible]$ $= -10$.

Problem.—Convert —10°C. into °F.

Solution.— $-10° \times 1.8 = -18°$.

And $-18 + (+32) = +14$. Hence —10°C. = 14°F.

NOTE.—*To add 32 means that the reading is to be 32° higher* [illegible] *scale.*

FAHRENHEIT TO CENTIGRADE.

Problem.—Convert 60°F. into °C.

Solution.—The first step to be taken is to find what woul[illegible] be the reading on the Fahr. thermometer if the freezing poi[illegible] were zero. This reading would be 32° lower than 60°, fo[illegible] zero on the Fahr. thermometer is 32° below the freezing poi[illegible] Accordingly, we substract 32° from 60°.

We have now ascertained that the temperature of 60°[illegible] equals 28° assuming the zero point to be where it is on th[illegible] Centigrade thermometer, namely at the freezing point.

Now 1°C. = 1.8°F.; then 28°F. must equal as many degrees C. as 1.8 is contained in 28°. Accordingly, we divide 28° by 1.8.

Thus— $28° \div 1.8 = 15.5°C.$

Whence the rule—

$$(°F. -32) \div 1.8 = °C.$$

Problem.—Convert 10° F. into °C.

Solution.—If the zero on the Fahr. thermometer were at the freezing point [where it is on the Cent. thermometer], the reading would be 32° lower than 10°, hence would be—22°.

Then—

$$-22° \div 1.8 = -12.2°C.$$

Problem.—Convert—10°F. into °C.

Solution.—If the zero on the Fahr. thermometer were at the

ezing point [as in the Cent. scale], the reading would be 2° lower on the scale than —10°, hence would be —42°. Then—

$$-42° \div 1.8 = 23.3° \text{ C.}$$

te.—It will be seen that (+32) is subtracted from a positive ntity [from an above zero reading] smaller than 32 by finding ifference between that positive quantity and 32; that differ- being a negative quantity, i. e., a reading beyond [below] ne zero point.

And that (+32) is subtracted from a negative quantity [from a elow zero reading] by adding 32 to the negative quantity, and lling the sum a negative quantity.

In short, *to subtract 32 means to find the reading 32° lower on the ale.*

Centigrade and Reaumur.

Problem.—Convert 15°C. into °R.

Solution.— 100° C. = 80°R. Then 1°C. = .8°R.

And 15°C. = 15 × .8 = 12°R.

Whence the rule—

$$°\text{C.} \times .8 = °\text{R.}$$

Problem.—Convert 15°R. into °C.

Solution.—Since .8°R. = 1.°C., 15°R. = 15° ÷ .8 = 18.7°C.

Whence the rule—

$$°\text{R.} \div .8 = °\text{C.}$$

Fahrenheit and Reaumur.

Problem.—Convert 60°R. into °F.

Solution.—Since 80°R. = 180°F., 1°R. = 2.25°F.

And 60°R. = 60 × 2.25 = 135°F. But since the zero of the R. scale is at the freezing point; the 135°F. must be counted from the same point. Hence 135° + 32° = 167°F.

Whence the rule—

$$(°\text{R} . \times 2.25) + 32 = °\text{F.}$$

Problem.—Convert 61°F. into °R.

Solution.— 61°F = 61 — 32 = 29°F. above the freezing point. Then— 29° ÷ 2.25 = 12.2°R.

Whence the rule—

(°F.—32) ÷ 2.25 = °R.

Problems.

503. Convert (a.) 25°C. into °F.; (b.) 80°C. into °F.

504. (a) 5°C into °F.; (b.) —5°C. into °F.

505. (a.) —30°C. into °F.; (b.) 2.5°C. into °F.

506. (a.) —2.5°C. into °F.; (b.) 1.1°C. into °F.

507. (a.) 125°F. into °C.; (b.) 25°F. into °C.

508. (a.) 5°F. into °C.; (b.) 5.8°F. into °C.

509. (a.) —5°F. into °C.; (b.) —1.1°F. into °C.

510. (a.) —25°F. into °C.; (b.) 31°F. into °C.

511. Convert (a.) 10°C. into °R. (b.) 10°R. into °C.

512. Convert (a.) —10°C. into °R. (b.) 10°C. into °R.

513. Convert (a.) —10°R. into °C. (b.) 1.1°R. into °C.

514. Convert (a.) 25°F. into °R. (b.) 25°R. into °F.

515. Convert (a.) —25°F. into °R. (b.) —25°R into °F.

TABLE OF ATOMIC WEIGHTS

According to F. W. Clark—1902.

Element.	Symbol.	Based on H = 1.	Based on O = 16.	Approximate.
Aluminum	Al	26.9	27.1	27
Antimony	Sb	119.5	120.4	120
Arsenic	As	74.45	75	75
Barium	Ba	136.4	137.4	137
Bismuth	Bi	206.5	208.1	208
Boron	B	10.9	11	11
Bromin	Br	79 35	79.95	80
Cadmium	Cd	111.55	112.4	112
Calcium	Ca	39.8	40.1	40
Carbon	C	11.9	12	12
Chlorin	Cl	35.18	35.45	35
Chromium	Cr	51.7	52.1	52
Cobalt	Co	58.55	59	59
Copper	Cu	63.1	63.6	64
Fluorin	F	18.9	19.05	19
Gold	Au	195.7	197.2	197
Hydrogen	H	1.000	1 008	1
Iodin	I	125.89	126.85	127
Iron	Fe	55.5	55.88	56
Lead	Pb	205 36	206.92	206
Lithium	Li	6.97	7.03	7
Magnesium	Mg	24.1	24.3	24
Manganese	Mn	54.6	55	55
Mercury	Hg	198.5	200	200
Molybdenum	Mo	95.3	96	96
Nickel	Ni	58.25	58.7	59
Oxygen	O	15.88	16	16
Phosphorus	P	30.75	31	31
Platinum	Pt	193.4	194.9	195
Potassium	K	38.82	39.11	39
Silicon	Si	28.2	28.4	28
Silver	Ag	107.11	107.92	108
Sodium	Na	22.88	23.05	23
Strontium	Sr	86.95	87.6	87
Sulphur	S	31.83	32.07	32
Tin	Sn	118.1	119	119
Zinc	Zn	64.9	65.4	65
Nitrogen	N	13.93	14.04	14